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JAMES JOHNSTON, SUPERINTENDENT

PREFACE TO VOL. VI.

At the close of a 6th Volume, I have only to repeat my thanks to Contributors and Subscribers, and to promise that every effort will be made to maintain the present character of these Papers in the future. There is at present no lack of matter, nor, with the increasing expansion of Public Works in India, is there likely to be any deficiency in this respect.

The new edition of Vol I. will soon be ready; and as the cost of the re-print will be less than that of the original edition, it will be sold at a reduced rate per copy. Vol. II. will also be put to press shortly.

The demand for back numbers has determined me to increase the number of copies of the next Volume from 1,000 to 1,500, which will also enable me to lower the price from 4 to 3 Rs. per number.

I may remind the public that nearly all the back papers are still available, *separately*, at 8 annas per copy.

The first Quarterly Number of Vol. VII. will be issued on the 1st February next. The subscription for the four Numbers of the Volume will be Rs. 12, whether paid in advance or in arrears.

But the current Numbers of the new Volume cannot be sent to those subscribers who have not paid up for Vol. VI.

J. G. M.

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No CCXIII.

NEW INFANTRY BARRACKS—SAUGOR.

Each barrack is designed to accommodate 36 men and 2 non-commissioned officers The upper story only is used as a dormitory, while the lower story is set apart for use as mess and recreation rooms, &c, &c. The masonry consists of rubble stone in lime, lime pointed outside, and lime plastered and whitewashed inside. The flooring is of flags The ceiling of lower story of main building is supported on wrought-iron girders, and consists of brick-in-lime arching covered with flags The remainder of the ceiling of lower story, consisting of two courses of flags, is supported on sál beams and burghas.

The roof of upper story of main building consists of double tiling, with flat and wheel tiles of the Goodwyn pattern. it is supported on sál trusses and battens. The rest of the roof of upper story is terraced and supported on sál beams and burgahs. The cost of each such half-company barrack has been about Rs. 75,000.

The plan given is that of the first barrack built.

In the remaining barracks, iron girders are all of one size and placed so as to rest on main walls, thus allowing cross walls to be removed hereafter, should it be found necessary to do so.

Saugor,
June 9th, 1868.

H. R. F.

No CCXIV

EXPERIMENTS ON DHARWAR TIMBERS.

By J. H. E. Hart, Esq, *Executive Engineer*.

The data regarding timber which are of primary importance to Engineers are—its weight, strength to resist cross strains, and durability, to ascertain these I directed my attention.

Weight, obtained only of seasoned timber, for, being at a distance from the jungles, it was not practicable to obtain specimens of newly felled trees. All the timber was at least one year in the log, and had all lain by, several months, in the small scantlings before being tested

The weights per cubic foot were in some cases got by direct weighing, in others were calculated from the observed specific gravity, using 62 4 as a multiplier.

Stiffness and strength under cross strains, of these I considered the former to be the more important and useful. A small deflection may cause considerable disturbance in the equilibrium of a structure, and its presence, if sufficient to catch the eye, will in most cases be very unsightly.

It will, moreover, generally produce these bad effects long before the limits of safety are reached, so that it is always necessary to calculate its probable amount, even when we have ascertained that we are within the limits of safety as to strength

The ultimate strength of a structure is seldom tested, and the value of experiments with regard to it, are chiefly to ascertain what load we may subject a beam to, and yet not approach within a certain fraction of that which would break it.

Ultimate deflections, although occasionally observed, are useless; and where any difficulty occurred, I have neglected them

The bars experimented on, were selected pieces of clean grain and rectangular section, they were supported at each end and loaded at the centre.

Dimensions and deflections were read on a box-wood scale, divided to 50ths of an inch. The arrangements for these experiments are shown in sketch appended.

In calculating the value of the constants or co-efficients, I have adhered to Barlow's Notation, his formula being,

$$\text{for stiffness or elasticity } E = \frac{W^1 L^3}{16\, b\, d^3\, \delta}$$

$$\text{and for ultimate strength } S = \frac{W L}{4\, b\, d^2}$$

W^1 = load in pounds not greater than the proof load.

W = breaking load in pounds.

L, b, d, δ = respectively the length, breadth, depth and deflection, in inches

E, the constant for elasticity or stiffness, is the same as that of the later editions of Barlow,* and is equal to $\frac{25}{a}$ of Tredgold,† or one-fourth of the weight of the modulus of elasticity, (Rankine's‡ and Mahan's§ E), it also equals 108 times the E used in Major Sankey's Tables.‖

S, the constant for breaking loads or for strength, is also equal to that of Barlow, is equal to 4 C in Tredgold, equals $\frac{R}{6}$ in Mahan, where R is called the co-efficient of Tenacity, or $\frac{f}{6}$ in Rankine, where f is called the modulus of Rupture.

Durability could only be tested by experiments extending over a great length of time, so that I am merely able to give data collected from the examination of constructions in the district. Remarks on the durability of each timber are given along with the description of it, but it is apparent that, as a general rule, unseasoned timber of all sorts, decays rapidly when denied ventilation, that the sap wood of all timber is subject to

* Barlow on Strength of Timber, by Heather

† Elementry Principles of Carpentry.

‡ Civil Engineering, by Professor Rankine

§ Mahan's Civil Engineering, edited by Barlow

‖ Professional Papers on Indian Engineering, No III, Vol I.

the attacks of white ants, and that all surfaces, when exposed to atmospheric influences, suffer some sort of disintegration (very probably through loss of essential oils) which renders their superficial fibres fit food for these insects. I have observed this action to go on year after year, each year the white ant clay is spread over the surfaces, which when removed shows that a slight superficial destruction has taken place, after which, all action ceases till next season, when the same process is gone through The arsenical solution puts an effectual stop to this I also find that a solution of arsenic preserves all matting and timber from the white ants, but that when exposed to the rains for a few months its preservative properties disappear, under cover, there seems to be no limit to the duration of its protective powers.

TRANSVERSE STRENGTH OF TIMBER.

Record of Experiments

Number.	Inches: L = length	b = breadth	d = depth.	Kind of timber and description of same.	Weight of C. F.	Whilst Elastic: 1st weight W^1	1st deflection δ	2nd weight W^1	2nd deflection δ	Ultimate deflection	Breaking weight	Description of fracture of specimen and remarks	$E = \frac{W^1 L^3}{16 b d^3 \delta}$	$S = \frac{W L}{4 b d^2}$
				AEEN (BLACK)										
I.	50	1	1	Kala muttee, Mairtee, Dr Gibson's No 16, *Terminalia glabra* *Terminalia coriacea* of Major Sankey, who places it in 1st class in his tables.	63 6	30	40	60	94	not observed	200	Cut from inside of log, grain straight bar warped laid with convexity side wise In breaking, lower fibre began to snap a few moments after which it broke	524687	2500
II.	50	1	1	The timber is hard, tough and heavy Heart wood of a dull claret color, outer wood about as dark as teak but without the red tinges of that wood. It is procurable up to 50 feet in length Logs have been brought into my office 40 feet long by 1 foot square	52 7	32	48	64	1 00	4 2	190	From outside of log, grain somewhat crooked Lower fibres gave first, splinter starting from about 3 inches from centre	506757	2375
III.	50	1	1	Stands exposure well, also, is sound under water; and, unless when slightly affected by decay, white ants do not attack it	61	32	50	64	·96	5 2	209	Warped like No 1 laid with convexity up, in breaking, beam had a sharper curve at one end than the other, fracture long	513798	2613
IV.	50	1	1	When alternately wet and dry, as at the water line in pile bridges and under the moorum in planking, it decays rather rapidly It splits considerably when exposed to sun and under the blows of the pile driver.	54	30	·42	60	90	2 7	160	Of low specific gravity, laid with outer fibres up cut from outside of log, chiefly sap wood, slight knot about 9" from middle, crackled much as weights were being added In breaking, a crack first showed at 13" from middle	558036	2000

Number	INCHES. L = length	b = breadth	d = depth	Kind of timber and description of same	Weight of C F	WHILST ELASTIC 1st weight W¹	1st deflection δ	2nd weight W¹	2nd deflection δ	Ultimate deflection	Breaking weight	Description of fracture of specimens and remarks	$E = \frac{W^1 L^3}{16 bd^3 \delta}$	$S = \frac{W L}{4 bd^2}$
V.	50	1	1	Is not easily worked by carpenters It has been the chief timber used in the numerous pile bridges in this district	60	30	50	60	1 04	2·9	164	Of low specific gravity cut from outside of log A shake at 6″ from centre, crackled at 120 lbs slipped on supports at 135 lbs, in breaking, gave in gradually.	468750	2050
VI.	24	1	1		60	50	06	100	16	92	407	Sound end of No V broken over again for this experiment, broke with splinter after last weight had been on several minutes	589091	2442
VII.	50	1	1		65	50	72	100	1 52	4 6	197	Flaw at 10 inches from end.	542534	2463
VIII	50	1 9	2 0		58	200	20	400	39	Not observed owing to danger of injury to scale from great weight used	1205	Formed partly of sap wood, but a sound beam Began to crackle at 800 lbs, and broke suddenly with long fracture 6″ from centre	513980	1982
IX.	50	1 9	1 9		59	200	19	400	36		1314	Sound beam A splinter started from one lower corner at 1311 lbs, and upper fibres showed signs of being crippled Broke gradually	671086	2415
I.	30	1	1 01	ARJONA, OR WHITE AEEN Billee muttee It appears that this is *Pentaptera arjuna*, No 151 of Dr Gibson	50	50	19	100	·38	1 4	315	Cut from outside of log, and therefore is chiefly sap wood	438844	2237
II	30	1	1	Closely resembles black Aeen, except in color, which is white	54 6	50	14	100	30	1 4	321	Contained some sap wood, 2 knots at about 6″ from centre on either side, gave way with a splinter, begin-	598566	2408

												ing at one of the knots. Broke suddenly after crackling at about 500 lbs load		
I	50	1	1 02	BABOOL. Acacia Arabica. Dr Gibson's No 19	52 2	32	44	64	1 00	4 4	223	Inner piece clean, crackled at 20 lbs, broke without notice by a short fracture, color of grain red	491352	2680
II	50	1	1	Wood very hard, durable and tough, of a reddish color, somewhat darker than teak, heart wood as dark as Aeen.	50 2	32	52	64	1 08	3 9	190	Outside piece clean, snapped with short fracture 2 minutes after placing last load, color of grain less red than last	468750	2375
III	24	1	98	Is not procurable in large scantling, does not split readily but is a difficult timber to work, grows in black soil plains Is attacked by white ants, lasts well under water	54 3	50	10	100	21	1 2	416	A good specimen broke at a point a little to one side of the centre The fracture somewhat diagonal Broke suddenly a short time after last weight was put on	457063	2600
I.	30	97	1·0	HONEE. Pterocarpus marsupium Dr Gibson's No 117 A pretty wood and easily worked, used in the interior	45 8	50	21	100	42	1 8	331	Grain of specimen slightly skew to bar Broke with diagonal splinter of about 1 3″ long, a flat wedge rising out of middle Began to crackle at 320 lbs	349901	2559
II.	30	1	99	of houses, said to be not very durable when exposed	49 3	50	19	100	37	1 8	389	A very fine specimen, grain clean fibres interlaid, broke suddenly a short time after last weight was added outside.	453832	2977
I.	50	1	1	TEWUS, OR TUNNUS, OR KOOREE MOOTHUL.	not taken	32	38	64	81	4 16	224	Fibres of wood laid outwards, began to crackle at 220 lbs, broke slowly by sinking gradually	632203	2800
II.	36	1	96	Wood hard, very tough, of light color, turning reddish when exposed to rain	51	50	34	100	70	2 5	222	Broke with a very fibrous fracture about 3″ long, the	485208	2081

Number	INCHES. L = length	b = breadth	d = depth	Kind of timber and description or same	Weight of C F	WHILST ELASTIC 1st weight W¹	1st deflection δ	2nd weight W¹	2nd deflection δ	Ultimate deflection	Breaking weight	Description of fracture of specimen and remarks	$E = \frac{W^1 L^3}{16 b d^3 \delta}$	$S = \frac{W L}{4 b d^2}$
HI.	30	·98	98	Dr Forbes mentioned to me that from the peculiar grain of this timber it is most useful for rollers for cotton gins, as it does not polish by friction and is therefore better for drawing the cotton fibre through, but for this cause also it does not work easily. It is durable when not exposed, nothing known of its durability when exposed. This wood is *not* as well known as its great toughness and strength would make it appear is desirable		·			·		·	fibres seemed to be locked into each other. A fine even grained specimen broke with a shortish very fibrous fracture bent very much before fracture and ends slipped forward on supports	473241	2602
I	50	98	98	TEAK	46.4	32	62	64	1.3	not observed	140	A slight knot and shake near middle broke after much crackling at flaw	438597	1862
II.	50	1	1	Sag—*Tectona grandis* Dr Gibson's No 100. Description of this well known timber is unnecessary, it is got from the North Canara jungles in logs up	52	32	58	64	1.16	3.5	168	Very clean piece, broke suddenly about 2 minutes after 1st weight was applied fracture beginning about 2" from centre	431034	2100
III	50	98	1	to 30 feet long, and of a diameter of 3 feet and over. Is not liable to	40.7	32	60	64	1.26	4.8	176	Grain slightly crooked near middle broke gradually fibres much interlaced fracture about 2 feet long	425170	2245
IV	50	1	1	attacks of white ants unless under decay. It bears exposure well, be-	41	32	54	64	1.12	not observed	140	Very clean piece broke suddenly with 2" splinter	462963	1750
V	5	1	1	coming black and very much ribbed under the weather, this seems to be from the softer resinous parts between	48	32	58	64	1.18	4.0	165	A knot about 1 foot from middle nothing remarkable in fracture, which was long and splintery	431034	2063

VI	24	1	1	the fibres being washed out All observations prove that N C Teak is not equal in strength to that of Moolmein or Burmah.	41	50	10	100	·21	1 2	404	This was sound end of No IV, broke suddenly with long fracture, an obtuse wedge *rising off top*	432000	2424
VII.	50	2	2		38	200	26	400	60	Not observed owing to danger of injury to scale from great weight used	1055	Broke suddenly with shortish fracture	340661	1648
VIII	50	2	2		40	200	38	400	76		915	Nothing remarkable in fracture	256977	1430

Summary of the preceding Experiments

Although these experiments were made with great care, yet they display considerable irregularity in the results obtained, and this appears to be inseparable from experiments on a material so variable as timber, where age, situation and soil, produce alterations in the character of different trees of the same kind; and even in the same tree, the part of the log from which the specimen is cut, or the position in which, during experiment, the fibres are placed, will also detract from the uniformity of result A mean of many experiments is therefore the only safe guide to the average results to be expected from a beam of a given timber. The following is a table of (mean) results of the experiments .—

Name of timber	Weight of C F	E	S	Remarks.		
Aeen,	59 25	543190 9	2315 6	A heavy and tough timber, strong and very stiff	Class I	of Major Sankey's tables
Arjoona, ..	52 3	518705	2322 5	Strong and rather stiff wood,	„ I	„
Babool, ..	32 2	472388 3	2551 7	Hard wood, toughish and strong, not very stiff. ...	„ I	„
Honee, ..	47 5	401866 5	2768	A wood of good average properties, tough, strong and light, but elastic and not very stiff .	„ II	„
Teewus or Tunnus,	51	530217 3	2494 3	A very tough wood, strong, stiff and heavy	„ I	„
Teak, ..	43 4	402304 5	1940 25	A light wood rather weak, brittle and not very stiff . .	„ II	„

J. H.

No. CCXV.

THE GOGRA CROSSING AT BYRAM-GHAT AND FYZABAD.

Report on certain Improvements in course of being carried out to secure a better crossing of the river Gogra, at Byram-ghât, in Oudh.

THE imperial road, from Lucknow to Baraich, crosses the river Gogra at Byram-ghât, 39 miles from Lucknow, at the point where the smaller river Chowka falls into it.

At this point the main stream of the Gogra runs from N E to S. W. On the right or Lucknow bank, just at the meeting of the two rivers, stands the bazar and village of Gunneshpore; opposite to which on the left or Baraich bank, stands the village of Byrampore, the direct distance between these places is about 7000 feet, which is the width of the bed of the Gogra below the point where the Chowka falls into it

The Chowka itself is a stream about 1200 feet broad in the rains, and it brings down no inconsiderable body of water

A tracing of part of a Revenue Survey Map, on the scale of one inch to the mile, is herewith given, and another tracing showing the site of road crossing, on the scale of one foot to the mile This latter survey was made in the cold season of 1866-67.

The bed of the Gogra at Byram-ghât in the dry season is full of dry loose sand, like the rest of the rivers in Northern India, the cold weather stream being between 1600 and 2000 feet wide, so that there remains about a mile of sandy tract for carts to traverse.

Up to last year the boat bridge had always been located below the junction of the two streams; its position varied every year, being on one occasion, at the village of Gunneshpore, and on another, a full mile below it,

and sometimes at an intermediate point, according to the freaks of the cold weather channel This necessitated the making of several metalled branches or off-shoots from the imperial road to the head of the boat bridge for the time being The right bank stands abrupt to a height of about 14 feet above the low water level of the Gogra, and a rough ramp down to the floating platform had to be cut nearly every year in a fresh place. All this was very unsatisfactory and a great obstruction to the traffic

In 1866 the Chief Engineer (Colonel Hutchinson, R E) ordered a survey of the river to be made, and plotted to a large scale, and subsequently determined to divert the imperial road so as to cross Chowka river by a boat bridge which should be kept up all the year round, then to traverse the "hâta" (or island between the two rivers) by a raised metalled causeway, and then to prolong this causeway some 1300 feet into the sandy bed of the Gogra, so as to contract that river's width in the rains and compel it to scoop out a deeper channel, in which it was hoped the cold weather stream would flow without splitting up, as it usually did, into two or three channels.

The principal reasons which led to the adoption of this line were—

I. That the large volume of water which, in the rains is carried down the right channel or "sota" (as it is locally called), of the Gogra, impinged directly on the bank on which the village and bazar of Gunneshpore stands, and threatened to carry away the place altogether, having already carried away about one-quarter of it. It was considered desirable to close this channel altogether so as to stop further erosion of the right bank of the river, and also to force the water that usually passed down it into the main or left channel of the Gogra, so as to deepen it permanently.

II. That the line taken by the ferry-boats which ply during six months of the year should coincide as nearly as possible with the line of the boat bridge during the cold weather, so that the greatest length of the metalled approaches to the boat bridge might be available for the traffic during the six months that the bridge was not in position.

Now a glance at the large map will show that, although it is a very simple task to cross during the rains from Byrampore to Gunneshpore, it is by no means easy to cross the other way; if the ferry-boat starts from Gunneshpore it is carried by the force of the stream a mile or more below Byrampore by the time it reaches the left bank, and has to be worked up-stream again with much labor, and loss of time; and if it be desired to

arrive at Byrampore direct, the ferry-boat must be worked up at least a mile against stream alongside the island—which amounts to the same thing

The head of the new diversion of the road will be a good starting point for the ferry-boats crossing over to Byrampore, they will shoot the opposite bank not very far below that village. Those crossing to the Gunneshpore side will follow the same line as hitherto.

III Some arrangement had become imperatively necessary for the accommodation of the large traffic in sál logs for which Byram-Ghât is famous. These logs are almost always stacked on the foreshore of the river Chowka, which is never eroded by the stream, and a branch metalled road, a full mile in length, must have been made from 38th mile stone to the Timber Ghât, even though the permanent crossing of the Gogra had been fixed below Gunneshpore, where it had always been hitherto So it was a saving of money to fix the head of the permanent crossing at the Timber Ghât, above Gunneshpore.

An earthen embankment was thrown up across the island with a bend at the 40th milestone, of which the top width was made 30 feet and the side slopes 4 to 1 The earth for this was dug on the down-stream side only, to a depth not exceeding one foot, and at a distance of not less than 200 feet, indeed, in many places, the alluvial deposit was not so thick as one foot; the side slopes were turfed with "doob" grass, which grows luxuriantly on the island.

The portion of embankment 1300 feet long, jutting out into the sandy bed of the river, has also been made 30 feet wide at top, with side slopes 4 to 1. The core has been made of pure river sand, and the top 3 feet, of slopes as well as of roadway, consist of alluvial earth brought at considerable expense from the island. The slopes on both sides, and the last 50 feet of the projecting end, were revetted with fascines of "jhao" (tamarisk) at least 1 foot thick, these were staked down with long babool sapplings. Both jhao and babool trees grow plentifully on the island.

In addition to the main embankment a series of protective works were undertaken. An earthen spur, nearly 1400 feet long, was thrown out from the high bank of the island at an average distance of 1000 feet above the main road, to ensure its safety during the first downward rush of the Gogra at the beginning of May.

This spur was made only 10 feet wide at top, the up-stream slope being made 4 to 1, and revetted with fascine work, the down-stream slope being made 2 to 1, and simply turfed. The core was pure sand, and the upper 3 feet everywhere, were of alluvium from the island It was curved at the end so that the impinging stream might be cast off, not too abruptly, into the channel of the Gogra.

It was expected that this spur would probably withstand the first heavy rush with which the rainy-season stream of the Gogra comes down in May, filling its previously dry bed from brim to brim, that a quantity of silt would be deposited between the spur and the main embankment when the turbid stream was brought to a stand-still in the quasi-bay, that probably a silting up of the channel would occur above the spur, due to its obstructive action, and that even were the spur to yield eventually, the breach would not take place until the main embankment had become consolidated, and the height of its crest above the bottom of the channel much diminished by the silting up of the enclosed bay.

These precautions were quite successful. The spur was not carried away at all, the channel above it did silt up during the first heavy flood, and a sand bar has been formed about 1500 feet higher up, which has closed the channel altogether for the coming cold weather, and has joined the sand island to the main island, the turbid waters did throw down their silt, when they were checked between the spur and the main embankment, and it is probable that in a couple of years more, the enclosed space will rise to the same level as the island in the river. This island, moreover, has now become quite covered with jhao plants, and alluvial deposits, and will shortly become part of the main hâta. And further, the village of Guneshpore has been saved from further destruction

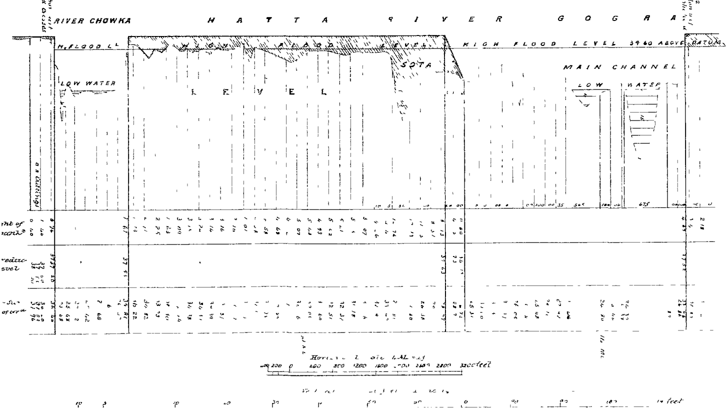
By these works, the main current has not been unduly thrown against the left or Baraich bank, during last rains it passed down the centre of the bed of the Gogra

The experiment having proved a success, it is proposed during coming cold season to complete the permanent boat bridge for the crossing of the river Chowka, and to sink a series of circular wells, so as to form a permanent masonry head to the main embankment where it juts out into the river Gogra.

On the Baraich side, there is a reef of block kunkur at the point where the embanked road recommences; on this excellent foundation it is pro-

THE GOGRA CROSSING.

Section of proposed line of Road at Byram Ghat



posed to build a permanent masonry head, consisting of a single circular bastion 90 feet in external diameter, the wall will be of large block kunkur laid in lime mortar, and the filling in will be of concrete to a certain height, and of rammed earth for the remainder of the distance to the top

After the rains of 1869, the whole of the causeway across the island and projecting into the bed of the Gogra will be metalled with kunkur

Besides the long spur thrown out across the sota, many other minor protective works were deemed necessary. Chief among these was an intercepting channel above the causeway across the island parallel with it, at an average distance of 1400 feet This was designed to prevent the banking up of the water in the numerous small nullahs and depressions that intersect the island by placing them all in communication with the river Chowka, so that the island is thoroughly drained directly the floods subside in the Chowka and in the Gogra, formerly these nullahs used to discharge themselves into the channel as may be seen from the map It was deemed quite inadmissable to leave any gaps in the embanked causeway, and even those nullahs which discharged themselves beyond it were closed by earthen spurs turfed with *doob* grass, as they were considered to come too close to the toe of the main embankment projecting into the bed of the Gogra.

This intercepting channel has been made with a bottom slope towards the Chowka of 1 in 2000, its side slopes were made 2 to 1, between points w and x the bottom width was 10 feet, from x to y it was 15 feet, from y to z 20 feet The earth and sand excavated were thrown up on the down-stream side of the channel, and dressed evenly so as to serve as a bund, the toe of this bund was placed 30 feet from the top edge of the cutting. This intercepting channel also has been a complete success, it does all it was intended to do.

The cost of all the works on the island and of the portion of embanked road thrown out into the Gogra has been up to date as follows :—

Main embankment.

	Rs
Earthwork, 20,84,000 cubic feet, ...	7,593
Turfing, 87,700 square feet, ...	219
Fascine work, ...	2,615
Total Rs, ...	10,427 (*a*)

Long spur across the channel.

	Rs.
Earthwork, 4,75,000 cubic feet, ...	2,413
Turfing, 14,700 square feet, ...	37
Fascine work, ...	1,832
Total Rs , ...	4,282 (b)

Intercepting channel.

Earthwork executed, 4,41,500 cubic feet, ...	962 (c)

Small spurs on island.

Earthwork executed, 1,48,000 cubic feet, ...	370
Turfing, 22,200 superficial feet, ...	55
Total Rs , ...	425 (d)

Grand total cost, up to date, Rs 16,096

But the experience of the past rains has shown that it will be advisable to raise the whole of the causeway across the island 2 feet higher, and the embankment jutting into the Gogra 3 feet higher. The estimated cost of doing this, and of again protecting the slopes with fascine work, is Rs. 9580. The estimated cost of the permanent head on wells sunk 30 feet is Rs 9580, and of the one founded on the kunkur reef Rs 2842 (the total cost for this sub-head being Rs 12,422).

The cost of metalling the whole length of 6200 feet with kunkur in three coats, 16 feet wide, and each $4\frac{1}{4}$ inches thick, is Rs 5600.

The estimated cost of the permanent boat bridge across the river Chowka is Rs 32,304. The long boat bridge across the river Gogra belongs to the Local Funds Committee.

Adding all these items together we find the probable cost of the project to be Rs 76,012, exclusive of the boat bridge across the main river Gogra. This is for a boat bridge about 960 feet long, and for a metalled causeway 6200 feet long.

BARABUNKEE, OUDH, November 14th, 1868.

A. PENNY, C E., *Executive Engineer, 2nd Road Division*

From the Executive Engineer, Fyzabad Division, to the Chief Engineer, Oudh.

Fyzabad, 3rd November, 1868.

Has the honor to submit a tracing of the Mangha embankment carrying the Fyzabad and Gondah road to the north (left) bank of the river Gogra.

The embankment itself is 30 feet wide at top, with sid
to 1, and is carried at a level of about 6 feet above highest

The spurs are about 10 to 15 feet wide at top, and l
about 2 to 1, and are carried at about flood level of riv
ment has stood without injury since its completion
the south end, where the river, which appears to be chan
gradually cutting away the end, and where a perman
is required

The work was commenced in 1862, by the constructio
tal bund 10 feet wide across the low land, this was repo
by the Executive Engineer and its completion to its ful
was sanctioned in December, 1865, at a cost of Rs. 21,7
estimate and of Executive Engineer's letter, (No 228),

The work is of the simplest character and requires n
description. It seems only necessary to remark that the
tion of a similar bund elsewhere should be taken from
side, that the excavation should be shallow and broad,
200 or 300 feet should be left between the toe of the b
of the excavation. The excavation should not be in a c
a strip of soil 25 to 50 feet wide at right angles to the
untouched at every 200 or 300 yards, if this precautio
possible that a branch stream might be formed in the
flood, which would endanger the embankment

The slopes of the bank and spurs should be well turfed,
spurs and embankment should be protected by a head
fascine work before each season's rains, and it is most desi
of the embankment itself be protected by a masonry gh

The spurs and embankment should be carried on a
above the highest known flood, all minor waterways be
the bank for a considerable distance should be bunde
stantial manner at several points, and if necessary, n
be cut to direct such streams into the main channel.

[Letter referred to above.]

To the Chief Engineer, Oudh.—No. 22

Fyzabad, 7

Sir,—During the months of May and June 186

causeway, 10 feet wide, was thrown across the low *mangha* or flooded land, between the town of Nawabgunj and the left bank proper of the river Gogra. This bank was found to answer satisfactorily that year, notwithstanding the hurried manner in which it was thrown up, and the Government of India in the following year sanctioned a sum of Rs 47,513 for the completion of this bank to the full breadth of 30 feet, with the surface to be metalled to a width of 16 feet.

Immediately after receipt of this sanction the floods of 27th September, 1863, occurring, and injuring the ground at the foot of the slopes the Chief Engineer directed that the bank should not be completed without further orders; and, consequently, nothing more since then has been done towards finishing it as sanctioned above.

In January 1864 a project was submitted for the protective works required to guard against similar floods to that of September 1863, which were subsequently sanctioned and finally completed. They were thrown up before the rains of 1864, but the floods being low and of little or no consequence, the result, although entirely satisfactory, could not be taken as affording sufficient proof of their utility. These works have also been acted on by the floods of the year 1865, but have suffered no injury whatever, the Gogra floods having risen to within twelve miles of the highest known flood level, but the extraordinary Tehree river floods of September 1863, have not again occurred, and, as previously reported, it is possible that they may not again occur for the next 50 years; it is therefore manifestly not desirable to postpone the final settlement of the question until then.

The experimental embankment it will thus be seen has now been tested by the floods of four successive seasons (i. e. from May 1862 to present date 6th December 1865), the injury done to it during this period has been the cutting away of some 800 feet altogether of its toe by the erosion of the left bank of a branch of the river which altered its course and gradually scooped out a deep channel where formerly it was fordable for six months of the year, the greatest part of this was done the first year. The further injury was the scooping out of a continuous channel parallel to, and at the foot of the embankment in September 1863, already mentioned, which however did not injure the bank itself, and for which the protective measures above referred to have, some time since, been sanctioned and completed.

The unfinished state of this experimental embankment, 13 feet wide, which is very high in some places, (from 9 to 16 feet,) is productive of serious inconvenience to traffic, as vehicles cannot pass each other without great danger, no actual injury has hitherto resulted, but it is not desirable to wait until a series of accidents and further inconvenience to traffic, &c., force the subject into more prominent notice.

Of the works sanctioned in July 1863, for the completion of this embanked causeway, the parts actually remaining to be finished, as shown in the abstract, amount to Rs. 33,176, for which I beg to solicit sanction.

NO CCXVI.

THE ABYSSINIAN TELEGRAPH

Report on the Telegraphic Material used during the Expedition to Abyssinia, with remarks on the subject of Military Telegraphy. BY LIEUTENANT O. ST. JOHN, R E

I HAVE the honor to submit a detailed report on the telegraphic material entrusted to my charge for use in the recent expedition to Abyssinia, together with a few remarks on the subject of military telegraphy, suggested by the experience gained during the campaign

To illustrate more clearly the points in which the material and apparatus were successful or deficient, I will first give a brief description of the telegraph, as erected along the road from Annesley Bay to Antalo, a distance of about 200 miles.

Supports —This line presented three well marked divisions: first, the belt of low land, 12 miles in breadth, between the sea and the hills, secondly, the tortuous defile, 50 miles long, leading to the highlands, and, lastly, the great plateau of Abyssinia. Of these the second alone presented any extraordinary natural difficulties. From Annesley Bay to Komaylé, at the entrance of the pass, the line was carried along the proposed course of the railway, for the first six miles on teak supports 20 feet in length, and afterwards on mimosa poles cut from the surrounding jungle, averaging not more than 12 feet. These were subsequently replaced by teak posts From Komaylé to the end of the pass, the line was necessarily carried close to the road, except where the spurs of the hills on opposite sides were close enough for the wire to be thrown in long spans from one to another. It was generally supported on mimosa posts, varying in different parts from 10 to 20 feet.

Cut from the jungle as the line progressed, they were of course green, and, though sufficiently stout, warped excessively in drying. In a few places insulators were fixed to trees, and sometimes, as in the Sooroo pass, to the face of the cliff. By the time the telegraph was completed to Senafé, the first station in the highlands, the bamboo supports ordered from Bombay had reached Zoulla, but such was the scarcity of carriage that none could be spared to bring them up to the front. Subsequently I had about 700 brought up by native carriage for use in parts of the country where no timber of any sort was obtainable.

For the remainder of the line from Senafé to Antalo, a distance of 130 miles, I was dependent on supports cut or purchased in the country. These were generally saplings of the juniper pine, from 10 to 15 feet in length, rarely exceeding three inches diameter at the base, and one at the top, and elastic as a fishing-rod. They were brought by the natives from considerable distances, and sold at prices varying from one to ten for a dollar. No insulators were used on this part of the line, the wire being simply passed through a notch in the top of the intermediate poles, and secured by three or four turns round the stretchers. Where the poles were exceptionally slight a tripod of three was formed to give stiffness enough to stretch to. The supports obtained in the country were placed from 40 to 60 yards apart, the bamboos from 80 to 100. On the latter, the wire was generally inserted in a nick cut with a saw in the side of the bamboo, about a foot from the top. Stays or struts were seldom used, being unnecessary, except at very sharp angles, from the lightness of the wire.

It is evident that a line so slenderly constructed would be more than ordinarily exposed to damage; except at road crossings, the wire was rarely high enough to allow a loaded camel to pass below it, and was almost everywhere within reach of a mounted man. Interruptions were thus very frequent, and the most constant vigilance and labor were necessary to keep open communication. The most fertile source of damage was undoubtedly the thieving propensities of the natives, which threats and remonstrances to the Chiefs proved of little avail to check. Next to this, were the interruptions caused by our own baggage animals, which, when relieved of their loads, rubbed themselves against the poles, and often tore down furlongs of line in the vicinity of the halting places.

Besides the main line of telegraph from Zoulla to Antalo, a line, 10 miles in length, was erected for the use of the railway, and a supplementary wire

was stretched through the pass between Komaylé and Undel, a distance of 25 miles.

The foregoing brief description will illustrate the following detail of the merits and defects of the various items of material and apparatus.

Wires.—For the main line, 350 miles of No. 16 W. G copper wire were supplied by Messrs. Bolton and Sons, of Manchester. It was wound on wooden drums, in lengths of from 1 mile 1,000 yards to 1 mile 700 yards, the average length being 2,700 yards, and weight, including drum, 120 lbs.

The main line from Zoulla to Antalo and also the railway line were entirely constructed with this wire. For 60 miles from the coast, only, insulators were used, but nothing could have been better than the working over the remaining 140 miles, where not only was there no insulation, but where the poles were mostly green Even in heavy rain no difficulty was found in working Spans of 400 yards or more were stretched in many places and stood perfectly well. For facility of stretching and jointing, conductivity and portability, nothing could have been more satisfactory than this wire. An iron wire of even half the electrical advantage of the 16-copper wire would have been three times the weight, and, apart from the larger amount of carriage it would have required, could not have been supported on poles of such tenuity as those necessarily used. Inspectors on repairing duty, again, were able to carry with them several hundred yards of wire to replace possible thefts by natives; with heavier iron wire, this, of course, could not have been done

Altogether, the selection of this copper wire was most fortunate, but it is not without its defects. First of these, is its liability to stretch during the operation of straining. No great force is necessary to decrease the sectional area of the weakest part of the wire by one-half, with a corresponding diminution of strength and conductivity. This defect can only, of course, be obviated by constant care, and by straining in short lengths.

The second demerit of copper wire is similar, but less obvious. I was puzzled for some time to account for the way in which many stretches of wire, originally strained with a dip of a couple of feet between each pair of poles, gradually increased this dip, while, perhaps, stretches close by and under similar conditions remained in *statu quo*. After some time I found that, as long as the poles were left untouched, and exposed only to the force of the wind, the wire on them remained unhurt, but if the posts were shaken violently, by cattle rubbing against them or other such cause, the vibration

communicated to the wire tended to elongate it, till it hung in festoons several feet below the original position This peculiarity necessitated frequent re-stretching in places where the supports were weak and exposed.

In the plain near Zoulla, approach to the poles was successfully prevented by piling brushwood round their bases.

Wherever the wire was carefully paid out from the drum, so as to prevent any kinking, I do not believe that there was a single accidental break, except possibly at a maker's joint, which are always weaker, I imagine from overheating whilst soldering, than joints made in the field.

The joint used was the ordinary German or twisted joint, eight or ten turns being taken on each side. The ends were occasionally brought over and twisted together to prevent the possibility of the joint drawing out No solder was used. The wire was stretched by hand on the ground wherever sufficiently level Hedger's gloves were worn by the men stretching, as the thin wire often cut through the skin and caused painful sores Where insulators were used, the wire was bound at every one. Much trouble arose from the insufficient strength of the drums, on which the copper wire was wound, to stand the terrible wear and tear of mule carriage The great heat shrunk the wood and loosened the screws binding the heads of the drum to the spindle. Careless muleteers will not take the trouble to lift loads from their mules, but let them fall on the ground. The drum-heads thus constantly came off, and the wire became kinked and entangled, causing much trouble and delay in paying out The drums, on which the Hooper's core and homogeneous wire were wound, suffered less, but were not altogether satisfactory Cart carriage being unobtainable, drums for wire or core might, I think, be made of wrought iron, without being much heavier, although, of course, more expensive than those of wood. If time, expense, or other reasons prevent the use of wrought iron, a spindle of that metal should be supplied with each drum. This, by means of a screw and nut at one end, would bind the drum firmly together, and the two projecting extremities would be useful in packing the wire on the mule saddles.

Fifty miles of No. 15 galvanized homogeneous iron wire were supplied for use on short lines near the coast, should such be required. From trials made in London on samples of this wire, it appeared far tougher and stronger, in fact more adapted in every way but conductivity, for telegraphic purposes, than the copper wire. In actual use, however, it proved far inferior. It was stretched only for the second line through the pass from

Komaylé to Undel, a distance of 25 miles, and proved unequal in quality, difficult to stretch, even in short spans of 80 to 100 yards, and often was so brittle as to preclude the use of the German joint I believe that this unsatisfactory result arose from overgalvanization Where the tin coating was smooth and even, the wire was fairly tough and difficult to break by kinking, but in many places where the galvanizing was unequal and ridged, a second twist was hardly necessary to snap it.

In reporting on the material required for a field telegraph in Abyssinia, Major Champain recommended that a small proportion of insulators should be supplied for use in forest country, and to provide for the possible necessity of carrying the line through swampy regions Under ordinary circumstances, a copper wire on bamboo supports would not require insulation. Two thousand brackets and the same number of spike insulators were accordingly obtained from Messrs Siemens. These insulators were used only on the teak and mimosa supports between Zoulla and Senafé Except for securing the wire to trees and rocks, they were of no great utility, and sometimes worse than useless, as the rough edge of the galvanized covering often cut the soft copper wire This was particularly the case with the spike insulators, which, though intended for trees, proved useful only for rocks, the bracket insulators being better adapted for the former

At first the wire was secured to every fourth insulator only, but it was afterwards found necessary to secure it to every one. The notch in the top of the insulator is thus useless

For a single light copper wire, such as that used in Abyssinia, insulators are quite unnecessary, except for carrying the line through forest or along the face of a cliff, the latter being a necessity which would rarely arise For forests the bracket form is undoubtedly superior to the hook and spike. The trees selected as supports are of course rarely, if ever, in a straight line, and thus the hook is pulled either inwards or outwards, so that the wire has not free play through it, and any advantage of a hook is lost. For tree work, therefore, I do not think that anything could be better adapted than the bracket insulator supplied for Abyssinia, substituting only a solid for the cleft head of that pattern. The method of fixing to the supports by means of straps answered admirably, but 50 per cent, extra nails and 20 per cent. straps should be supplied, the waste of both being considerable. For fastening wire to rocks, the spike insulator answered fairly, but the spikes were too short and of too soft iron. Steel

spikes, two feet long, would have been of the greatest service. Wherever a shrub could be found growing out of the rock, the wire was attached to it instead of to an insulator, insulation being obtained by binding one or more folds of sheet india-rubber round the stem.

The method in which the insulators were packed was admirable. One hundred, with straps and nails, or spikes complete, were held in a stout wooden box, two of which formed a mule load. Each contained a complete set of tools and materials for fixing the insulators and stretching the wire, consisting of hammers, gimlets, files, cutting pliers, scissors, fine wire, twine, and emery paper, besides a couple of pieces of sheet india-rubber. Of these, however, the wire and files were not used. The empty boxes proved most useful for containing small stores, records, &c.

Fifty miles of Hooper's core was supplied for flying lines, to be laid upon the ground for communication in action or with outposts. This core consisted of a copper conductor of three strands, tinned over, and covered with several coats of india-rubber, prepared according to Hooper's patent It was wound on wooden drums, in lengths of 700 to 880 yards, each weighing from 110 to 140 lbs. To have carried a portion only of this material with its equipment complete would have necessitated a train of at least one hundred mules, a number which could not have been spared from the more urgent requirements of the Ordnance and Commissariat

The greater part of the Hooper's core was left, therefore, at Zoulla, the instruments intended for the flying lines being, moreover, required for the intermediate offices on the main line, which were required in far greater numbers than had been foreseen. A few drums of core had, however, been sent up to Senafé when first landed, and with these a line of about two miles was laid to the head of the pass. As far as insulation went it answered perfectly, but lying, as it did, day after day, along the high road, it proved an irresistible temptation to the natives, who managed to steal many yards daily without detection. It was therefore replaced as soon as practicable by an aerial line.

I have thus hardly had a fair opportunity of judging of the Hooper's core as a material for flying lines All I can say is, that neither the heat nor damp of Zoulla appeared to have in any way affected it. Its only fault seemed to be want of strength in the conducting wire. Five strands of similar dimensions to those used would have been preferable to three.

One pattern of carriage for paying out and picking up was used both for

the large drums of core and the smaller of iron and copper wire. Twelve were taken out, seven or eight of which were used, and, with the exception of some of the minor fittings and of the woodwork of the wheels, were as perfect at the end of the expedition as when they left England. They were made at Messrs. Siemens' factory at Charlton, under Major Champain's superintendence, and answered the purpose for which they were intended perfectly. A model was sent to the Royal Engineer Museum at Chatham. On these carriages I can suggest no improvement, except that spare wheels and handles, in the proportion of a pair of the former and three of the latter, should be sent with each carriage.

Signalling apparatus.—Three descriptions of signalling and recording apparatus were sent to Abyssinia. For the main or semi-permanent line eight relay instruments (with writers) were supplied by Messrs. Siemens. The same firm supplied twelve smaller recording instruments for the flying lines, on similar principles to the first, but without relays. Four magnetic instruments obtained from Messrs. Henley were also taken out. The last were only used on the short line of railway telegraph, where they did good work. Of their suitability for transmission of signals through long lengths of wire, I am thus unable to speak, but they deserve a fuller trial, and their defect of non-recording is, I think, almost, if not fully, compensated for by their requiring no batteries. For aerial lines it might possibly be difficult to protect them from lightning, but for ground or buried lines I believe that magnetic instruments would, with complete signallers, prove preferable to all others.

To return to the signalling apparatus used on the main line. The larger instrument consists of a signalling key, ordinary relay and printing apparatus, and two vertical galvanometers, without translative connexions. Owing to the inability of the signallers sent from India to signal so as to print intelligibly, an inability caused by the fact of non-recording instruments being used in India, the printing part of the apparatus was not used in Abyssinia. Of the remainder, the relays, connexions, keys, and fittings generally were admirable, but the galvanometers were very defective. Their resistance was so great that from the first it was found necessary to cut them out of circuit for rapid working, and a very short time rendered them useless even as detectors. The smaller instruments were similar in construction, but had no relays, and simple horizontal galvanometers. These were infinitely better than the more elaborate detectors at-

tached to the larger instruments, and I was compelled sometimes to detach them for use with the latter, both however had the fatal defect of being very liable to injury during transport

For all rough work, not only campaigning, but wherever instruments have to be carried on pack-saddles, or even on carts, over rough ground, galvanometers should be invariably detached, and several spare ones supplied The experience of Abyssinia only bears out what I had previously remarked in Persia, where the attached galvanometers gave constant trouble, and had often to be replaced by extemporized indicators.

As regards the working of the instruments, large and small, apart from the galvanometers, nothing could have been more satisfactory Even the small field instrument, without relay, worked by a twelve-cell battery, sent and received satisfactorily through 120 miles of uninsulated wire. Translating connexions would, however, have been most useful on the larger instrument.

Batteries —The batteries used were all those known as "Marie Davy's carbon and zinc," the acid employed being protosulphate of mercury. They were obtained from the same makers as the instruments Each element consists of a carbon cell, covered with vulcanized india-rubber This contains the protosulphate of mercury, reduced to a paste with water. In it is the zinc part, hollowed out to contain water, and prevented from touching the carbon by small wooden plugs. These elements were in sets of twelve and twenty-four, for the lesser and greater instruments respectively, enclosed in teak boxes, the lids of which held india-rubber washers, to prevent leakage when closed during carriage. Each box held besides, a syringe for charging with water and a tin of spare acid For the relays of the large instruments, sets of six elements on the same principle, but square in shape and more powerful, were provided All were sent out ready charged, but while the small round elements were found in perfect order on unpacking, the relay batteries were much deteriorated. Action to such an extent had set up in them that the zinc was already half eaten away, and, in fact, after working a few weeks, they became quite useless. The other batteries, though hardly coming up to the expectations formed of them, either as regards lasting powers or convenience, did very well, and, electrically speaking, left nothing to be desired. Their defects were, the necessity for recharging with water two or three times a day; the great care and time this operation required, a care which it was difficult to get signallers to

take, and the rapid deterioration of the copper straps, caused by leakage while travelling, and the unavoidable spilling of water during recharging. It was supposed that the carbon parts would require renewal sooner than the zinc, and spare parts of the former only were taken out, but the contrary proved to be the case, as, towards the end of the campaign, many zincs had nearly corroded away, while the carbon parts remained almost unimpaired. Fresh protosulphate of mercury was required about every two months, more from wasting than from deterioration. Taking them altogether, I think they are the best batteries I have seen for field purposes. Had the elements been a little larger, it would have been an improvement, spare zincs and straps are also required, and the action of the acid on the pewter syringes is such as to make it unadvisable to carry the latter in the box with the elements.

A small chest containing a box of repairing tools for instruments, covered wire, earth-plate, Morse paper, and ink, accompanied each instrument. The addition of magnets only was wanted to make them complete.

Office stores.—For the offices on the main line, tents complete were ordered from India, but they were sent without floor-cloths or furniture, so that these had to be improvised. Latterly, I used the tables and stools provided for the flying offices on the main line.

The stools were ordinary camp stools, of extra strong construction; the tables were simple planks of mahogany, the legs screwing into battens underneath. Not one of either was broken or needed repair after six months' work and some hundred miles of mule carriage.

Six india-rubber water-bags were taken out to carry water for the earth-wires of temporary offices. Although not much used for this purpose, they were most useful in taking out water to working parties. I was astonished at the amount of rough usage these bags stood without injury; even the terrible mimosa thorns seemed unable to damage them.

The globe lamps for burning oil were strong and useful, but a candle lamp would have been preferable.

Strong silver watches would also have been better than the portable clocks provided.

The small bivouac tents for the temporary offices on the flying lines were hardly used, but seemed well adapted for the purpose for which they were intended.

Line stores.—Crowbars were principally used for digging holes for sup-

ports Twenty-four were taken out, but proved insufficient, and I had to obtain others from the Engineer Park. A portable forge for repairing these and other tools, and grindstones for sharpening axes, were often much required The ten American axes provided were invaluable, but insufficient in number. Of bill-hooks I had fifty, and most useful they were. The remainder of the line stores do not call for much remark, except the india-rubber boat, which, though never required for telegraphic purposes, the line of country traversed crossing no river, proved useful in surveying and sounding Lake Ashangi

Stationery—The stationery supplied only lasted out the campaign with great economy, with the exception of record books and message forms, of which ample remained. All was admirable in quality

Stores for twenty miles of line on iron standards.—Early in January, when the difficulties of keeping open the first section of the line from Zoulla to Sooroo appeared insurmountable, owing to the damage done by the numbers of sick camels grazing in the jungles, His Excellency the Commander-in-Chief, at my recommendation, telegraphed to England for 200 iron standards, with twenty miles of iron wire and stores complete By the time they arrived, the final march from Antalo on Magdala had commenced, and it was more than probable that the campaign would be brought to a speedy close. Moreover, the measures taken to guard and improve the line had had such effect that no interruption had taken place on the section in question for nearly a month. Again, all available labor was required for other purposes, and I therefore did not disembark the stores in question, which were sent on to Bombay I am therefore unable to report on them.

Lime light apparatus—No letter informing me of the despatch of the lime light apparatus reached me, and I only accidentally discovered its arrival, and then too late to get it up to the front in time for the operations before Magdala, where it might have been useful. On the return march, however, during a short halt at Senafé, I experimented with it; but from a defect in the apparatus, which there was not time to remedy, was unable to make sufficient hydrogen gas for a satisfactory trial. The system of obtaining this, viz., by passing steam through red hot iron filings, differed from that I had formerly seen (by acid), and, in spite of the difficulty of carrying acid, is, I think, inferior to that method for use on a campaign.

Photographic stores.—The only other stores which were at any time un-

der my charge were the photographic and army signal stores. The former, I, by direction of Major-General Sir Charles Staveley, then commanding in Abyssinia, gave over to Major Pritchard, R E, a few days after landing.

Signalling party.—Within a fortnight of arriving at Zoulla, I sent Lieutenant Morgan, R E., who had charge of the signalling party, to Senafé, then the advanced post My own more urgent duties in connexion with the telegraph did not permit me to join the head-quarters of the army, with which the signalling party remained throughout the advance on Magdala, where they did good service, and I am therefore unable to say anything regarding the stores Lieutenant Morgan's melancholy death on the return march, from fatigue and exposure, deprives us of the interesting fruits of his experience, but the Non-Commissioned Officers of the signal party which has returned to Chatham, where the apparatus was prepared, will, I have no doubt, have much valuable information to communicate. I will only remark that the apparatus for signalling between ship and shore was not found necessary owing to the short distance separating the anchorage from the beach.

Bamboos.—Owing to the uncertainty as to whether timber for supports would be found in the country, Major Champain recommended that 10,000 bamboos should be supplied from India. I have already explained why so little use was made of these

Teak poles of very good quality were substituted for a part of the bamboos, and most of the remainder were cut in half and jointed in Bombay to facilitate transport on pack animals. These jointed bamboos were a failure The few that were taken up country were carried by natives at a higher rate than those left entire, and the difficulty of fitting the tops and bottoms together was great As simple supports they answered passably, but it was impossible to stretch on them. Had camel or mule carriage been available, the jointed bamboos would doubtless have been easier of transport than those left whole; other advantage they had none. Almost all were of excellent quality.

Disposal of material at the close of the campaign.—From Antalo to the Egypto-Abyssinian frontier, a distance of 140 miles, the wire was taken down and brought to the coast, the telegraph office at each halting place remaining open till the night before the march of the rear-guard. From the head of the Senafé pass to Zoulla, the wire had been secured to each insulator, and, therefore, from the great heat and rapidity of the march down, I was unable to bring away the line in the pass.

At my recommendation, His Excellency the Commander-in-Chief directed that the army signal and lime-light stores should be returned to England, and the telegraphic material sent to Bombay, with the exception of the 20 miles permanent line which was required for use at Aden. But this had not been discharged from the ship which brought it, and as there was a large quantity of other material lying over it in the hold which would have taken much valuable time to remove, I acquiesced in the proposal of the Senior Commissariat Officer that it should be sent to Bombay. At this time also there was no means of sending the lime-light apparatus to England, except *viâ* Suez, and I therefore requested that it might be taken to Bombay for transshipment. The signalling stores which had been provided by the War Department remained in charge of the 10th Company, Royal Engineers, and were brought by them to England with their regimental baggage.

The telegraphic material was handed over to the Commissariat for shipment, and I directed Mr. F. Hervey, one of the Assistants sent me from India, to take charge of duplicate packing lists for communication to the authorities at Bombay.

Remarks on Military Telegraphy.

I now beg leave to submit a few remarks on the subject of telegraphs in warfare, suggested by the experience I have had the opportunity of gaining in Abyssinia.

A British army may possibly be again called upon to wage war in a barbarous country at a distance from its base of operations. To an Officer called upon to superintend telegraphic communication on such an expedition, I believe that the records of my experience would be of much use, and even to a campaign in more civilized lands, wholly or partially provided with a system of telegraphs, many of my remarks will be applicable.

The subject naturally divides itself into two sections, construction and organization.

Construction of a military telegraph.—It may, I think, be taken as an axiom, that to supply the telegraphic wants of an army advancing on a line of communication more than 100 miles in length (*i. e.*, that distance separating the advance column from the base), a double wire is absolutely necessary; for more than 200 miles a third wire, and so on. For an army wholly dependent on its base for supplies, as was the army in Abyssinia, I would

add a second wire after the first 50 miles One wire would be set aside for through traffic between base and head-quarters, with translating stations at the principal depôts, the other wire or wires would serve as means of communication between the minor stations, one of which should be at each halting place A reference to the following table of the traffic on the telegraph in Abyssinia will show the difficulty of carrying on the work of an army with a single wire, and the large share of traffic contributed by the minor halting places

It may here be mentioned that messages were rarely sent to the offices for transmission but between 10 A. M. and 10 P. M. I began by keeping the principal offices open at night, but soon found the uselessness of so doing, except when important messages for England were expected from the front.

The last month only (May) gives an adequate idea of the work which would have devolved on the telegraph had circumstances permitted its advance with the head-quarters.

FROM			January	February	March	April	May.	TOTAL
Zoulla,	..	..	165	333	399	324	518	1,739
Komaylé,	..	..	175	309	302	200	446	1,432
Sooroo,	..	..	..	108	187	119	240	654
Undel,	..	..	..	127	218	134	327	806
Rarayguddee,	..	..	..	96	200	137	413	846
Senafé,	.	.	..	146	370	250	507	1,273
Focado,	..	..	..	.	..	16	52	68
Addigerat,	..	.	..	.	215	175	171	591
Adabaga,	..	..	} No records kept.					
Dolo,	..	..						
Head Quarters,		.	.	..	18	170	251	439
TOTALS,		..	840	1,119	1,939	1,525	2,925	7,848

Any one conversant with the details of traffic on a line of telegraph will see that a single wire much subject to interruptions would be quite inadequate to the transmission of so large a number of messages, averaging nearly 40 words each, exclusive of addresses and official instructions. The number would have been much larger had not restrictions been placed on the power of officers to use the telegraph. This was at first practically unlimited, but the privilege of signing messages for transmission was afterwards restricted to Commanding Officers and Officers of the Quarter Master General's Department. This limitation produced a marked diminution in the traffic (*vide* return, months March and April).

The next question for discussion is the description of line to be erected. This must, of course, vary to a certain extent with circumstances, but the line, if likely to be required for more than a few days, should be as strong as if intended to be permanent.

A telegraph on a line of communication is subject to more chances of injury than one through a similar country unoccupied by a military force. Camp followers are more mischievous and careless than ordinary travellers, and, apart from any hostile demonstrations, all the worst classes of natives may be expected to hang about the march of an army The constant passage of troops does little to protect the telegraph, which should thus be constructed to stand as much rough usage as possible. Economy of carriage, if not of money, would, as a rule, prevent the use of iron standards and heavy wire, but, except under the circumstances of total absence of wheel carriage, lighter material than No 12 iron wire on strong bell insulators should not be used. For two or three wires, I would not place the poles further apart than 70 yards, or 25 to the mile, with ordinary 18 foot poles If the base of operations be on the sea coast, iron standards might be used with advantage for the first 50 or 100 miles

About 20 to 50 yards from the road is the best distance for the line Road crossings should be, of course, avoided as much as possible, and struts used instead of wire stays If the march of the army to the front be so rapid as to prevent the erection of a substantial line to accompany it, a single flying line without insulators might be erected at the rate of 10 miles a day A second working party working at half that rate would follow, insulating the first, putting up a second wire, and generally finishing the line.

When the telegraph material was prepared for Abyssinia, our knowledge of the country to be passed through was insufficient, and all that could be done was to take out material adapted, as far as possible, to any circumstances; and for the erection of a line from Senafé onwards over the table land of Abyssinia, nothing could have been more suitable than the copper wire and bamboos supplied But for communication between Senafé and the sea, I would have provided a double line of 60 miles supported on iron standards Operations should have commenced at both places, from Senafé with the light line to accompany the march of the army, and from Zoulla with the permanent line to connect Senafé, the base of operations in the highlands, with the sea.

Working parties must, of course, vary with the nature of the troops

mployed and the country A company of native troops properly supervised an put up five miles a day of line over ordinary ground To accompany he march of an army, two companies working independently would be equired.

Organization of a military telegraph —With regard to the organization f a military telegraph, the first question that suggests itself is, under what epartment of the army should the telegraph be placed? It may be xpected that the "*personnel*," at all events of the higher ranks of the elegraph, will, as a rule, be furnished by the Royal Engineers, and the ontrol of their operations would thus naturally fall to the Commanding Engineer But the construction and maintenance of the lines are the only ngineering part of the duties of a Telegraph Officer The direction of ines, the organization and control of officers and traffic, are equally imortant, and have more in connexion with the Quarter Master General's, r Intelligence, than the Engineer, Department In Abyssinia, the control f the construction of the line was subordinated to the latter, but its direcion, management, and traffic to the Quarter Master General. This arangement, though no inconvenience arose from it in Abyssinia, would ot, I think, work well in operations on a more extended scale

It is now, I believe, proposed to place the control of the system of telegraphs in England under the Post Office, or rather to unite the Telegraph Department to be created with the postal This system is, I venture o suggest, admirably calculated to promote the efficiency of both telegraphic and postal arrangements on a campaign

The advantages of such an arrangement are many. In small stations, he necessity for double staff would be obviated; the postal duties, ordinarily entrusted to some officer who seldom willingly undertakes them and is liable to be removed at any time, could be easily and efficiently discharged by a telegraph clerk accustomed to the ordinary business routine of a telegraph office. In larger camps, the civilian Postmaster would better perform his work, under the supervision of the commissioned telegraph officer, who again would supplement and arrange much of his traffic through the post during interruptions, and would inspect both departments on his tours. Finally, both should be represented at head-quarters by a single chief, as director of communications, who should receive orders through the chief of the staff.

The flying telegraph, for use in action, and the army signal department

should be entirely separate, and subordinate to the Quarter Master General's Department.

The staff for an army telegraph I should therefore organize as follows:—

A director to remain at head-quarters, having control of postal arrangements, in addition to his telegraphic duties. Two, three, or four assistants, according to the length of line likely to be erected, in the proportion of one to every hundred miles. They should be military officers, if possible. The disadvantages of employing, on a campaign, civilians in positions necessitating constant official communication with officers of all ranks and departments are great and obvious, and I would prefer, as an assistant, a hard-riding subaltern of Engineers, though previously unacquainted with telegraph work, to a civilian, however well acquainted with his duties. It would, however, be desirable to have a civilian traffic manager at the base of operations, or with the head-quarters.

For the subordinate staff, if soldiers thoroughly qualified in the duties of telegraph clerks could be found, they would be preferable to civilians, but the training in the telegraph school at Chatham, though an admirable groundwork, does not qualify men for more than the manipulation and management of instruments. With the exception of two or three, who had been employed as telegraph clerks before enlistment, none of the forty or more men of the Royal Engineers who have served under me in telegraph duty during the last four years, were fit for the charge of offices on leaving Chatham, although a few months' experience thoroughly qualified most of them for independent charges. Better material could not be had, practice only was wanting, and this they have no opportunity of obtaining. If it should be desired to have a thoroughly trained body of military telegraphers fit to take charge of and work lines in a foreign country at a day's notice, some one or more of the public lines in England should be entirely managed and worked by the Royal Engineers. This would give a trained staff, which could be transferred, complete in organization and material, to a seat of war. Failing such, I should prefer civilian clerks, entrusting the conservancy of the line to trained Sappers. These should be mounted, and armed with a sword in a frog belt, and a revolver carried at the waist. The regulation equipment of the telegraphers of the Royal Engineers in Abyssinia was a source of constant annoyance to the men and of delay in the service. Even during construction, the heavy rifle and ammunition was much in the way, and on interruption and

inspection duty was so irksome, that rifles were sometimes left behind, though against orders, and the men went out unarmed. This resulted in a corporal receiving three severe wounds, and losing his mules and baggage, on being attacked by natives.

A man cannot comfortably carry his rifle and ammunition when mounted, and to send men on foot to inspect and repair a long section of line is to expect impossibilities.

In conclusion, I beg to submit a list of the total establishment I should think necessary for the construction and maintenance of a line of military telegraph, 200 miles in length, half of which is a double line, with two terminal, three intermediate translating, and twelve minor and observation, stations.

General Staff.

1 Director.
2 Military Assistants, one at head-quarters and one at the central station
1 Civilian Assistant, as Traffic Manager

	Head Clerks in charge of large offices	Signallers	Principal Inspectors (Sergeants, R E)	Line Inspectors	Instruments, translating	Instruments, ordinary
2 terminal Stations, -	2	8	2	4	2	2
3 intermediate ditto -	3	12	3	6	6	6
12 minor ditto - - -	...	12	...	12	...	12
	5	32	5	22	8	20

An equal number of spare instruments should be provided with commutators and lightning dischargers for all stations

The stores for each station, including stationery, should be packed separately.

No. CCXVII.

IRRIGATION IN THE DECCAN.

By LIEUT.-COLONEL J. W. PLAYFAIR, R.E.

THE irrigation in this part of India presents this point of speci erence to that in the North-west Provinces of the Bengal Pres and Madras, viz, that whatever their other difficulties may be, th throw the waters of their rivers on the lands that specially require tion, while we on our present system cannot. In the North-west F ces, the canals have to contend against an excess of slope of the c through which they pass, which is overcome by masonry falls at the sary intervals to retain a certain slope in the canal bed; for instan Ganges Canal, leaving the parent stream at Hurdwar, has several fa fore it reaches Roorkee, and as it goes on towards Cawnpore, cor to require these descents: after passing Roorkee, it attains the ba or watershed of the country, and commands a great extent of la wards the Ganges on one side and the Jumna on the other. In Madr principal canal irrigation is confined to the Deltas at the mouths three great rivers, the Cauvery, Godavery, and Kristna, where whe a dam of moderate height is built, the canal soon gets out on the s to command without further difficulty large tracts of land specially r ing artificial irrigation In the Deccan and Southern Mahratta co in the first place the rivers have so slight a slope of bed, that ever such a small fall as 9″ to 1 foot in a mile in the canal, the fall of th does not gain much on it, and this, coupled with the steep tran slope of the valleys, prevents the canal getting away to any distanc the river itself; instead therefore of watering the dry and compar

barren lands some distance from the river bed, the canal meanders through the already fertile land immediately in the vicinity; and this, being fertile without the canal, though its waters of course are a benefit to it, they are not of such consequence as they would be further away. The annexed rough sketch A will illustrate this

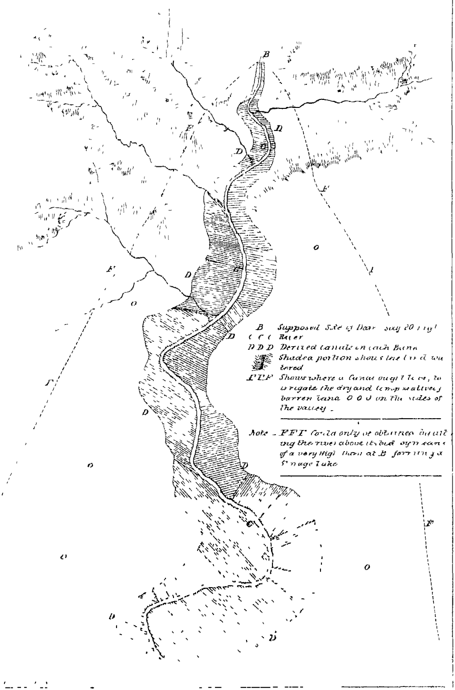
This is one difficulty, the next is of even more serious importance the invariable supply from the monsoon rains of the Western Ghâts fills to overflowing all the rivers that have their source there, but only during and immediately after the wet season At this time the land being already watered directly from the heavens, does not so much require an artifical supply The first or Khureef crop fructifies in most seasons moderately well without the assistance of the rivers It is when the long dry season of nearly eight months sets in, and the land gradually becomes dry and parched, that the rivers are looked to, but they have then nearly run dry, the copious monsoon supply is gone, and a mere thread of water in comparison remains, and that thread decreases to almost nothing towards the termination of the hot weather

To make the irrigation works pay, and to be of real importance to the country then, we require to effect two things · the one, the commanding the barren lands on the side of the river valleys, the other, the retaining some part of the copious streams that run to waste during the rains, and to store them up till they are needed in the dry season. Works adapted to such storage solve the first problem also, as they must increase the height, and therefore command of the waters above the country.

Our native predecessors in the part of the country I am reporting on, though thoroughly alive to the value of water for their lands, made but very partial efforts to solve the above two problems. Their storage works were confined to small tanks on tributary streams, useful in their way, but affording a very small area of irrigation in comparison to the country unwatered. The main rivers, as far as storage is concerned, were untouched. The tank system, as carried out by them, as a rule, may be stated not to be a paying one, looking merely to the money profit on the capital sunk, simply because the dam and appurtenances cost too much in comparison with the value of the water stored, calculating such value by the extra revenue that the land irrigated by it pays. Many of the existing tanks were not made with the mere view of creating revenue. In many instances they were absolutely necessary to the neighbouring

IRRIGATION IN THE DECCAN.

SKETCH A



villages to supply water for man and beast, and as such were often erected as works of charity, the using the surplus supply for irrigation to gardens below being in these cases the secondary, and not the primary, purpose.

It is only to such tanks or lakes then in which the value of water stored for irrigation bears such a proportion to the cost of storage works (dam, waste weir, &c.) as to realize a profit on the outlay (without reference to other considerations), that our attention as irrigators should be directed, and it will be found that, save under very exceptional circumstances, the scale will not be turned in favor of profit until the tank becomes a very large one, and to supply such immense reservoirs, we can only look to the large rivers, that is, we must find favorable sites on their courses where they can be dammed up at a profitable cost, which involves good features of the country for the dam and waste weir, and a sufficient area of land of good quality accessible to irrigation at a moderate cost for the supply canal works.

The latter requires little consideration There is an unbounded area of land in a proper position to be watered and to pay handsomely for it, the difficulty lies in making the supplying lake, and that that difficulty may be appreciated, I may remark that works on the scale required are quite without precedent. The reservoirs in Europe are quite in miniature in comparison,* and there are few, if any, in this part of India. I know of but one, and that a failure. I shall refer to it again further on

Being therefore without Engineering precedent, and offering in itself plainly the risk of the greatest disasters, one naturally approaches the subject with hesitation and caution, and yet if we are to irrigate this country in the proper way its features indicate, we must grapple with it.

But before continuing, I will digress to make a few further remarks on the works of our predecessors; as they have done so much, and in their way so well, that surprise will be expressed at my saying they have never carried out such works as I indicate as necessary.

Let it be remembered that I am confining myself to the Deccan and Southern Mahratta country, but I believe Khandeish, our best canal irrigated district, offers no exception.

The native irrigation was then of two sorts, either by tanks, or canals

* Mr. Ellet proposed works of this kind at the head waters of the Mississippi and Ohio Rivers in America, but they have not as yet been carried out.

For comparison, it is not the height of the dam that should be looked to, but the capacity of the waste weir, as the latter shows the magnitude or otherwise of the flood to be contended with.

direct from rivers Their tanks are, as a rule, small, and erected on streams of little volume, as may be judged from the small capacity of their waste weirs. The dams are of moderate height, and, what is of the greatest importance, the flood over the waste weir has but a small fall, and is of manageable proportions, in the only instance I know where these conditions were not fulfilled, a disastrous failure was the result, it happened to the work I before alluded to, a large tank * (near the village of Sut Koty) on the Mysore frontier of the Dharwar Districts

Here the natural features of the country afforded a magnificent site for an enormous tank, a comparatively small but well-supplied river passed through a gorge in the hills, before approaching which, the country was open, and the transverse slope towards the river slight. Some enterprising native, for the true name and history generally is lost, constructed a dam of vast dimensions (actually 800 feet thick at bottom) across this gorge, and not contented with this mass of earthwork, revetted it with Cyclopean stones, particularly at the point where the river channel ran. The dam stood well, and is perfect to this day, but no sooner did the tank fill, than the river either sought for itself a waste weir, or found a small one made for it This question cannot now be decided, because at this point, which was on a saddle of the natural hill, and of pretty hard rock, the water, rushing over with violence, and having a fall of 100 feet or more to reach its old bed, tore through and created a cut with almost perpendicular sides, through which it now runs nearly at its old level, thus making a new course for itself, and by contemptuously turning the artificial impediment of man, rendering his vast labors useless

This is an excellent lesson for all who follow in that designer's footsteps, and the obviating the cause of his disaster will be found one of our great difficulties, which I shall again refer to. (Since writing this, I have found the following paragraph in a report of Colonel A. Cotton's, on a proposed lake of this description, called the Maury Tank) Speaking of such works and their requirements in the way of waste weirs, he says, "there are the remains of many vast bunds in such situations in different parts of the peninsula, I believe they were all breached, because their constructors had no idea of what was wanted in this way." So much for the native tank system; as a rule, it is, where successful, on too small a scale and too costly for our purpose. I am aware that there are very large tanks in the

* The Maduk Tank

Madras Presidency which pay a large revenue, but the features of that country must be different, from the comparatively small height of their dams and small volume of water passing over their waste weirs, they show none of the difficulties of construction and maintenance which appear in those we require, and, as I have shown, where they have been exposed to such difficulties, they have failed

The other native system was that of canals direct from rivers, of which we have an excellent, nay magnificent, instance in the works on the Toongbadra Here enormous stones were thrown in dry across the numerous rocky ridges in the river bed, so as to create dams or rather weirs of moderate height From the head of water thus afforded, canals on either bank were supplied The same system was applied in other rivers, only in smaller instances, the dam or weir would probably be of masonry, instead of simple rough stone. The canals so formed could not, from the peculiar features of this part of the country, get away to any distance from the parent river, and only supplied irrigation to a small belt of a mile or two wide on its bank, where the land was already fertile without artificial irrigation It is this principle we have followed in our own works, not only on the Toongbadra, but elsewhere. We have made more scientific dams, but we have not been able, any more than our predecessors, to get our canals into that part of the country really requiring them.

I wish it to be understood that these works are profitable, and that we shall continue to carry them out, but that they utilize a very small portion of the monsoon supply, and make but little mark on the face of the country. I repeat that the real irrigation called for by the natural features of the land is a storage tank system, not on the small scale of old, but boldly seizing on the great rivers; and therefore believing I have noted the principal points which prove this to be the true requirement, and also that it is plain to us all that the plentiful waters of the monsoon should be kept in the country till they are wanted, I return to the subject of storage tanks on a large scale.

It is easy to prove that such tanks are wanted; it is not so easy to design and carry them out. I have remarked that we have no precedent, European or native, to guide us, or rather that there is no European precedent at all, and the only Native one I know under far more favorable features of ground than we shall probably find, was a complete fail-

ure, from the same causes that will put all our skill to the test to combat.

The two great difficulties will be the Dam and its Waste Weir. The dam must be of massive strength and have sound foundations. We are going to pile up a waste of waters above the country so great that if the dam bursts, they may carry death and desolation for miles and miles along the valley below. The massive strength is a question of cost and skill merely, the foundations are a more difficult matter.

Many a promising site in other respects fails in this, but I do not think we are justified at any rate in the infancy of this sort of work to proceed without securing it. (For instance, the report I have recently received from Mr Brown, in Khandeish, shows that the site near Roxana, selected by Colonel Fife as likely to afford an excellent storage lake, fails from the river bed being nothing but sand, and by a difficulty amounting almost to an impossibility in obtaining sufficient width for a waste weir. Were we to throw a dam across the gorge, as proposed, lifting the water up to 100 feet above its natural bed, it would either leak away through the sand under the dam, or burst through, blowing the dam up.)

The other and greater difficulty still, is the waste weir. We are not dealing with a petty stream that would make a pretty cascade down the hill side, but with an impetuous torrent, a large river in flood formidable enough in its own bed with a moderate fall, but how much more so when it is thrown down a slope of a height nearly, if not quite, that of the Falls of Niagara.

My predecessor, Colonel Fife, has, in the Poona water supply project,* grappled with one of these large tanks, and with great boldness, not contented with the great height of his present intended dam (85 feet) to the surface of the lake, he contemplates making it 30 feet higher, so as to be in all 125 feet. Knowing the risk to be run, he paid the greatest attention to his project, which he prepared, aided by all the resources of his great irrigational experience and natural engineering skill. He was, in my humble opinion, too bold in the dimensions of his dam, to which, when carried out, I shall endeavour to persuade Government to add some more masonry. He had also turned his attention to some other storage lakes on a much larger river (the Girna, in Khandeish), the project for which is at present in abeyance, owing to the vital want of sound foundations.

* *See* No. CLVI. of these Papers.

Many other sites for valuable storage offer, and will continue to offer themselves, but we must proceed cautiously, not recklessly. There are yet many of the simple canal works, offering but little risk and a good profit, to be carried out, which will keep us fully employed. Of the storage works, I should recommend Government to complete the Poona one first to its full extent, observe its advantages and defects, and then take it as a precedent to be, if successful, copied or improved upon in others, but not to commit themselves at first incautiously to many of these so necessary but hazardous undertakings

Having thus, though in a brief and cursory way, indicated what I think must be the ultimate style of irrigational works to be carried out in the Deccan and Southern Mahratta country, I continue, by reporting on what is actually being done at the present moment, and what it is proposed at present to recommend, it being recollected that the eventual large storage tanks contemplated, so far from interfering with, or rendering the present works useless, will, by the increased supply of water in the dry season they can afford to them, increase their utility, while though it is some time before cultivation takes full advantage of a canal, still those being and to be made, will be adding to the revenue of the country each year, and affording means for further development of irrigation on a large scale.

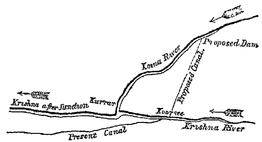
I will first remark on the canal from the Kristna, near Kurrar, in the Sattara Collectorate, as it is a work fast advancing to completion, and will be a very fine example of the canal system, as it can only be carried out without vast storage reservoirs As this is intended to be a mere general report, I will not cumber it with details, which would be better given in a special one

The work consists then of a masonry dam of moderate height (about 20 feet) thrown completely across the river bed, founded on a rocky ridge, which is itself a barrier or dam, and materially assists in giving a head of water.

From above this dam, and with its bed 4 feet below the crest, a canal is excavated, provided with proper scouring sluices to keep its channel open, and a short distance down, and at a convenient point thereon, a head or regulating sluice is erected by which floods are shut out, and only the amount of water required, by the canal admitted at will.

The canal then meanders on with a slope of 1 foot per mile, carried a-

cross the transverse drainage of the country by proper masonry works, and gradually receding so far from the bank as to command a belt of land between it and the river, too narrow, I am sorry to say, for the wants of the Kristna valley. It is most painful to see fine land, capable of most profitable irrigation, lying but a few feet too high on the wrong side of the canal (This is one of the evils spoken of in the commencement of this report. We want a greater head of water than our style of work in the Deccan affords) Towards the tail of the canal, however, this previously narrow belt widens out very considerably; in fact, the canal is, as it were, only beginning to tell on a large area of country when it terminates.



Terminates, because by the time it has gone this distance, the supply of water in the dry season will have been exhausted on the land already passed through, but if we could by any means increase the summer supply, it might be prolonged with great advantage to do this it is proposed to endeavour to find a suitable site for a dam over the adjacent river Koina (as above), and to throw all its summer water into the Kristna above the present dam, which will materially aid the supply. The monsoon waters of the Koina may probably be in part utilized by a future canal along the right bank of the Kristna, after the junction of the two rivers, but this may rest for after consideration. There is a prospect also of our being able to make a storage lake on the Koina, which, in conjunction with the proposed dam and short canal across to the Kristna, would give us such a supply, as to enable the existing canal to be prolonged, and to fertilize a large tract at and beyond the point where it at present terminates. This supplement to the original design is now being surveyed for. There are hopes also of being able to obtain the small summer supply of the Yerla River, which our canal crosses at a favorable level.

Should the supplementary works I have noted turn out to be practicable, the Kristna canal will afford much more summer irrigation than

at present intended some alterations will then have to be made in the designed section and fall towards the tail, and this infers no delay in carrying out the present project, as some time must elapse before the work reaches the point at which the levels are intended to be altered This is the only irrigation work actually in progress in the Sattara Collectorate I recently inspected it and found it in good progress, the dam, head works, and first 10 miles of canal, should be ready before this year's monsoon, so that water can be admitted at once.

I visited also another small but finished work at Rewadee, in the vicinity of Sattara. An old native work that had failed had here been restored, and that so recently, that the cultivators had hardly got over their first doubts as to its success. They were now however appreciating its value, and jealous of any interlopers. Foreseeing that the demand would soon be greater than the supply, I wrote to the Collector, pointing out how valuable to the revenue this work would soon become, and begging that for the present, only temporary rates should be levied, with the object of raising them to their full and fair point after a year or so, and if properly managed, very high rates may be easily obtained, as the stream is perennial, and the ground commanded will become a garden.

We next come to the Belgaum Collectorate, where little if anything has ever been done in the way of irrigation, but where the rapid at the head of the Falls of Gokak, seems prepared by nature as a site for a canal I copy here the principal portion of a report I recently made to the Revenue Commissioner on an irrigation project at this place.

"This river, taking its rise in the Western Ghâts, has, like most of those in the Deccan, a full supply of water during and immediately after the monsoon, that is, until the end of November the supply for irrigational purposes, may, as Captain Wingate says, be called (practically) unlimited, but very soon after the termination of the rains, the stream dwindles to a mere thread in comparison with its former volume. On the 17th instant (i e, February) I gauged the amount then running, and found it to be only 50 cubic feet per second. Colonel Fife, who made a similar measurement the year before, a few days earlier, found a similar quantity, and this amount of 50 cubic feet will probably dwindle down to 25 or 30 feet before the end of the hot season (I am aware that in April and May casual freshes may be expected, but these soon run off without leaving the perennial supply augmented.)

"Profitable irrigation from this river, therefore, must first of all extensively employ the monsoon water for crops of rice and other cultivation for which irrigation up to the end of November will suffice, must, at the same time, store as much of the monsoon flood as possible in tanks along the line of the canal, and finally, use the remaining perennial stream in the canal, and the stored-up water in the tanks, for sugar-cane and garden crops, the supply for which should be most carefully looked to to prevent waste, and be charged for at high rates, fairly settled with regard to the value of the crops fertilized by it

"The natural facilities of the Gutpurba for all the above-mentioned descriptions of irrigation are very great, we are provided at once without cost with the first great requirement, a starting level (in this case 200 feet high), commanding an immense acreage of valuable land; for the river runs gently from the Ghâts through the country, until it passes the village of Konoor, when it falls for about half a mile in rapids over sheets of rock, and finally leaps over a sheer precipice into the plains below, affording a most beautiful, nay sublime, spectacle

"On the right bank a range of rocky hills accompanies the course of the river for some time before the falls are reached, and offers a great obstacle to a canal, which would have serious difficulty in getting through it, and once through, a ravine, caused by the Markundee river, would give additional trouble, but on the left bank, about two miles above the falls, the hills fall to a mere ridge, on cutting through which, the canal at once comes upon a contour, which can be carried through the hills without difficulty until it dominates a fine plain of at least 400 square miles, lying between its course and the river, and finally reaches the crest of the watershed between the Gutpurba and the Kristna, thus affording irrigation to a part of the latter's valley also.

"The natural features above noted suggest the following scheme, which will in all probability be found feasible at a paying outlay when actually surveyed —

"(*a*) To throw a dam or weir across the river at the nearest practicable point to the lowest part of the ridge to be cut through. The selection of the site for this work will require a careful instrumental survey. There is an excellent one (as far as a rocky bed and rising rocky banks to carry the wings into are concerned) just at the commencement of the rapid, some distance below the town of Konoor, but as the river

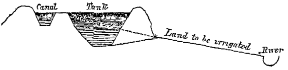
is already ponded up at this point, and runs back very much on a level to the town of Konoor, which is situated on a rather low bank, there is some fear that any extra afflux caused by the dam, might in heavy floods inundate it. Moreover, the left bank at this point being nothing but sheet rock, the initial cutting would I fear be found very costly.

I should prefer, if possible, placing the dam above the town of Konoor, where the bed of the river is again rock throughout, and being dry, and above the pond, evidently has a considerable command over the lower site, which will decrease the initial cutting, and moreover, having no town immediately above to be flooded, the dam can be raised higher An advantage, as in this case, it will I think be found much cheaper to raise a foot of dam than excavate an extra foot of canal. I foresee difficulties however which may render this upper site impracticable The river runs in three channels, and the banks are very low.

" (b). Then from above this dam, on the left bank of the river, to make a canal of such a capacity as to be able to carry the extreme monsoon supply that can be utilized. Such a canal to be carried as much as possible on a contour line, so as to avoid expensive excavation or embankment, the more so, as from the great height above the plains from which it starts, its bed will be in hard and probably rocky ground for a great portion at any rate of its course As this canal during the hot season will carry a very small supply, which would be wasted by absorption and evaporation if thrown on a wide and shallow bed, its section should be narrow at bottom and broadly widening out above.

" (c) Along the course of this canal, tanks should be made at every suitable site, the selection of a suitable site, after the practicability is once determined, involving simply the consideration of cost in comparison with the value of the water stored. These tanks should be so arranged, that their surface level should be that of the canal in full volume, their waste weirs should be very large, so as to act as an escape as well for the tanks as the canal, and the sluice gate supplying them should if possible be self-acting. The freshes in April or at other times should be taken advantage of to refill them. The general feasibility of their construction is evident; the canal is so high above its parent river, that allowing a considerable loss of head for the depth of the tank, its bottom must still be above a great extent of land.

Thus—*



"I think I have noted all that is necessary to show the description of works proposed and their practicability, a few words will suffice to show the prospect of their being remunerative

"In the first place, nature having done so much, the works should not be costly in comparison with the amount of land to be irrigated, or in other words, with the profit to be realized.

"The quantity of land commanded by the canal is more than can ever be irrigated, therefore, the demand for water will be greater than the supply, which ought to tell well upon the rates to be levied

"The only doubtful point in the project, is the fact that throughout all the first part of the canal the land to be irrigated belongs to Jagheerdars, and is not directly under Government control, but Jagheerdars know the value of water as well as tenants holding immediately from Government. This doubtful point has already been discussed. Captain Wingate thought that there would be no difficulty."

Instructions have been prepared for Lieutenant Smith, who has been appointed the Executive Engineer for Irrigation in this part of the country, it is to be hoped he will now be able quickly to mature a completely detailed project for submission to Government.

Another important river is the Mulpurba, which taking its rise in the Western Ghats, has the constant full monsoon supply, but as usual a mere stream in the lower part of its bed in the hot weather. Colonel Fife gauged it at Khanapoor on the 19th December, and found only 31 cubic feet per second. I gauged it at the same place on the 24th February, and found 21 cubic feet per second.

This river has been looked to by Collectors and others, and lately by His Excellency Sir Bartle Frere, Governor of Bombay, not for the mere irrigation of the land in its vicinity, but for that of the Dharwar cotton

* I only indicate sites for tanks in this position, as likely to be found, as the canal contours round the valleys In some cases, however, it may be preferable to make the tank lower down the valley, with its flood surface considerably below the canals, but still well above a large area of country between it and the river.

plains, throughout which water is very scarce. The reason that the Mulpurba supply has been supposed likely to be available, is that, on its course near Somudutee, there are some very remarkable features. A line of hills crosses the track of the river, through which it passes by a very narrow chasm or rent, which offers great facilities for a dam even of stupendous size. The Trigonometrical map also shows that the backbone or division of the watershed is close to the river at this point, and to the eye, the bank or crest that forms the watershed is of no great height. (The tracing from the Trigonometrical map, which accompanies, should be here referred to.) How simple does it seem to throw a dam across the gorge somewhere between the villages of Katurhal and Kulolee, and lead the water away either through the valley by the village of Hoswal or by that of Kurreckuttee.

Moreover, it does not only seem simple on the map, but it does also to a person on the spot. The eye however is not always to be relied upon.

Some years ago, in consequence of a report made by Mr. Shaw, then an Assistant Collector, who proposed a dam as above, and a cutting by Hoswal, I took some levels from Hoswal downwards towards the river. I have not the papers by me, but my recollection is, that finding there was a rise of 110 feet, and that I had not commenced nearly at the crest, I gave the project up as hopeless. I have now again taken it up, still I fear with little hopes of success. Much more surveying however is required before finally reporting it as impracticable. This we know, however, that the work in any case must be one of enormous magnitude. The dam across the gorge must be of great height, and the river having but a small fall of bed, the inundation will go far back up its course. From the nature of the valley, barren hills with a little strip of cultivation on the banks of the river, and also from the want of water elsewhere, the villages will be seen to be close to the river all the way along. They would *all* be submerged, and the little strip of land whose cultivation supports them would be lost also.

Even this dam of stupendous height, say 130 feet, would not raise the level of the surface to the crest of the ridge. A cutting of an extreme depth of 50 feet and of $3\frac{1}{2}$ miles in length, *vide* the accompanying section, taken at Kurreckuttee, would be required in order to tap the upper 30 feet layer of the tank only. When this was done, and not till then, the water would come out on the Dharwar plains.

The next thing to be looked to is the waste weir; some channel for the surplus water must be formed or cut (I fear the latter) through the range of barrier hills, over which a flood of waters must be passed and thrown down a slope of 130 feet or more to the parent river in the neighbourhood of Manolee

Altogether, taking into consideration the loss of property and land involved in the long inhabited valley that would form the tank's bed, the enormous and costly works required to utilize the supply when found, and the doubt whether the extra profit to be raised from the already fertile Dharwar plains would at all pay a remunerative percentage, I myself consider the scheme as one never likely to be undertaken

Colonel Fife, who had heard reports founded on my former examination (for I believe I was the only one who ever took an instrument to the place), suggested, that instead of attempting to draw water so low down as this, we should commence our works as high as Khanapoor, or rather at a rocky barrier about $1\frac{1}{2}$ miles above that town.

I have recently visited Khanapoor and the rocky barrier alluded to, and have also traversed the whole valley from Khanapoor to Manollee The result, so far as I yet know, and the irrigating the Dharwar cotton plains is concerned, is still very unsatisfactory. From the map and look of the country, one would naturally suppose that a canal with a moderate head at Khanapoor would cross the ridge at Kurreekuttee, but our old enemy, the want of fall in the river, again interferes. A contour for a canal, with a fall of one foot per mile, has been run from the ridge at Kurreekuttee to the village of Toomurree, at which point, after winding at a terrible loss of fall for miles, round the valleys, it was still 160 feet above the river. Knowing the hopelessness of carrying such a contour on further, I ordered the leveller to drop 50 feet and proceed, intending to recover that fall by a cut through the Kurreekuttee ridge The result was, that on arriving at the barrier, $1\frac{1}{2}$ miles above Khanapoor, his level was still 106·89 above it, and the line had traversed 124 miles from Kurreekuttee. The barrier at Khanapoor is 32 64 below the ridge at Kurreekuttee, although 36 miles up the valley as the crow flies. The ridge at Kurreekuttee, is 156 feet above the river in its immediate vicinity. These levels are very unfavorable; the survey is still being proceeded with, to try if a large storage lake is practicable at Khanapoor, in which case, supposing the canal to start 50 feet above the barrier, and to cut through the ridge at Kurree-

uttee at a depth of 50 feet, it would have a fall of 67 feet between the two points, with which it may probably be successfully led through the valley.

The following are the plans for irrigation from the Mulpurba that present themselves for examination, and which are in course of being finally decided on one way or another :—

(1.) To make a storage lake at Khanapoor, and from a high level, to lead a canal cutting through the dividing ridge somewhere near the village of Kurreekuttee, and finally watering the Dharwar plains.

(2.) Or, this being impracticable, still to make a storage tank, and to water both sides of the Mulpurba's own valley.

(3.) Or, to do the same without a storage tank. This latter offers very little prospect of profit indeed. The land on the margin of the river, as far as where the main road to Dharwar crosses, is already a mass of rice fields irrigated directly by the rainfall, which is here very abundant.

(4.) To make an enormous lake by damming up the gorge between Katurhal and Kolole—*see* preceding paragraphs.

(5.) The country has been levelled for a site for a dam near Manolee, but nothing profitable can be done, owing to the hills again coming precipitously down to the river about Toragul. A dam might be made below Ramdoorg, and a belt of irrigation obtained along both banks. This is but a small work, and a lame conclusion to the vast projects we have been speaking of, it may be found eventually worth taking up, and very likely be the *only paying project on the river*.

No other schemes for Dharwar and Belgaum are at present projected. I know the Dharwar districts well, and that save some altogether minor and doubtful works, there is nothing to turn our attention to save the Wurda River. I have examined it (when Executive Engineer, Dharwar) for almost the whole length of its course in the Bombay Presidency, and and never hit upon any scheme to ulitize its waters. I believe a large storage tank would be the only likely plan, and a site for that would have to be sought higher up its course in the Mysore districts. There are two works, the important part of which I executed before I left Dharwar, viz., the drawing water out of the Muduk tank by a new sluice, and the dam and canal over the Kulhala nullah near Misreekote. The former has now been handed over to me, and as soon as Lieutenant Smith is settled in his appointment, I will take charge of the latter also.

On visiting Sholapoor on my return, I found the cantonment and town very much in want of a good supply of water I sent a report to the Superintending Engineer, Southern Division, giving my advice as to the best way of repairing the existing tank, &c, but the true remedy is the construction of the magnificent tank at Ekrookh,* for which the plans and estimates have long since been sent in to Government by this Department.

Fall in feet per mile of different rivers in the Deccan and elsewhere.

DHARWAR DISTRICTS—	
Toongbadra river ...	2' to 2½' per mile.
Wurda river,	2' „
BELGAUM DISTRICTS—	
Malpurba river,	1¼' to 1½' „
Gutburba, below the falls of Gokak,	1', 2', and 14" per mile.
SATTARA DISTRICTS—	
Krishna (above Dam at Koorsee),	4 7' per mile.
Koorsee† to above Bahey falls, ...	1 9' „
Bahey falls to Yerla junction, ...	1 4' „
Below Yerla junction, ..	0 6' or 7½" „
Koina (from Helwak to Kurrar),	1 3' „
from Kurrar to above Bahey falls,	0 4' „
from Bannolee upwards,	6' „
Yerla (from Krishna junction to Chicklee),	8 8' „
Maun (from Deeguchee to Munswur),	5 5' „
POONA DISTRICTS—	
Neera (above Ramhswur),	4 6' „
Inderownee ...	2 75' „
Bheema (Surwalee to Deksal,	2·75' „
SHOLAPORE—	
Seena (above Oonduganm), ...	2·75' „
GANGES—(at Sookertal), ..	1 5' „
(Gurmuktesur to 60 miles south), ...	1 25' „
(Cawnpoor to Allahabad) ...	0 75' „
JUMNA—(at Agra),	1 25' „
INDUS—(towards Sukkur),	0 75' „

* *See* No CLXXVII. of these Papers.

† The greater part of this fall is at Koorsee

No CCXVIII

THE MISSISSIPPI REPORT.

Report on the Physics and Hydraulics of the Mississippi river. BY CAPTAIN A A HUMPHREYS *and* LIEUT. M. L ABBOT, *Corps of Topographical Engineers, U S Army. Philadelphia,* 1861.

THERE are probably few Executive Engineers in India who have not constantly to make surveys of rivers and streams in order to determine their discharges in time of flood, and at intermediate stages—to fix the water way of bridges to be built over them—or to estimate the effect of cut-offs and embankments on their regime.

The formula generally used in calculating the discharges is Etylwein's, and it has been shown by the operations of the Mississippi survey to be incorrect when applied to natural streams

It is thought then that a more extended notice than that given in No. CLXXXVII. of these Papers, of the method followed by the writers of the Mississippi Report in deducing their formulæ giving the relation existing between the cross section, slope, and mean velocity of a river, cannot fail to be interesting to the readers of this periodical.

After completing the experiments described in Colonel Anderson's very interesting paper on what may be termed the interior economy of a cross section, the first step of the experimenters was to collect all the observations made, especially for the purpose, or published in standard works, and apply to them all formulæ ever proposed for the mean velocity of water flowing in open channels of known dimensions and slope.

The result was not satisfactory, as may be seen by referring to Tables I. and II. given in the Appendix. It was found that there are two classes of formulæ applicable to water moving in open channels: those based

upon the supposition of uniform motion, and those based upon the supposition of permanent motion.

The former requires that the cross section of the channel shall be invariable and the slope of the fluid surface constant. In other words, if the stream be divided into straight filaments parallel to the direction of its motion, the velocity may vary for different filaments, but not at different points of the same filament.

The condition of permanent motion is different. The cross section and slope may undergo changes, provided, however, there are no sudden bends to produce undulation, but the discharge through the cross sections must be constant. The filaments may vary from point to point in diameter, and, consequently, in velocity, but they must be unvarying in discharge.

The only difference between these two classes is that the one has not, while the other has, a term which takes into account the changes in living force produced by gradual changes in cross section. Such a term would involve the most extended system of soundings and a greater refinement in the calculations than the exactness of any determination of the amount of water to be measured could justify.

The supposition of uniform motion was therefore adopted. The condition of this motion, that each particle of the fluid shall pass through the corresponding points of the several elementary cross sections of the channel with equal velocity, can never be strictly fulfilled in a natural channel, but, by selecting stations where the bed is most regular, a certain approximation to this condition may be obtained. The error should be corrected by the constants, provided the observations from which they are deduced are properly conducted.

The truth of Du Buat's two theorems, that, when water is moving uniformly, the total accelerating force is equal to the total resistance; and that for all open channels, the accelerating force arises solely from the slope of the water surface, is considered to be undeniable.

The first indicates the most simple way of deducing such a formula, viz., to equate expressions for the accelerating and retarding forces.

The second suggests an expression for the former, viz., the product of the weight of water by the sine of the slope of its surface, a quantity which, in practice, may be assumed to be equal to the fall in a limited distance, divided by this distance.

The accelerating forces are therefore represented (for nomenclature, *see* Appendix) by

$$G g a l \frac{h_1}{l}.$$

An expression for the resistance must be deduced.

It has been demonstrated by experiment in the preceding notice, that there is a strong resistance to the movement of water applied when it comes into contact with the air, and second, that this resistance whatever its cause may be, is of the same nature, as that at the bottom and sides of the channel, since the law of transmission through the fluid is the same in each case One resistance then may be compared to the friction arising from the forcing of a solid body through a pipe. Its *locus* is the entire outer elementary layer of the fluid, and for want of a better name, it may be called the resistance due to the adhesion of this layer to the foreign bodies forming the inner surface of the great natural pipe. It retards the velocity of this outer elementary layer, but directly affects no other The velocity of every other particle is diminished in accordance with the laws of an entirely different resistance, viz, that of the *cohesion* of the different particles to each other This is properly a secondary resistance, being that which regulates the distribution of the effects of the primary resistance of adhesion

Among the different interior particles of the moving mass, the force of cohesion is of a different order from that of adhesion, and of far greater intensity

It admits of only a very slight difference of velocity between the different consecutive elementary layers of the fluid, while that of adhesion allows a velocity often amounting to several feet to exist in the outer layers of the fluid The deduction of an Algebraical expression for the retarding forces based upon these views is very simple It is evident that the retarding forces are primarily consumed in overcoming the resistance of adhesion, cohesion acting merely to govern the transmission of the effects of these resistances through the fluid

But the absolute resistances of adhesion are directly proportional to the length of channel considered, multiplied by the circumference of the fluid or $l\,(p + W)$ and to some function of the mean of the velocities of all the elements of the outer layer of the liquid. But U_0 is the mean of all the surface velocities, and U_r that of all the bottom and side velocities. Hence the expression for the mean of the velocities of all the elements

of the outermost layer of the fluid is $\frac{U_0 W + U_r p}{W + p}$ The resistances of adhesion are therefore proportional to $l\ (p + W)\ \phi \left(\frac{U_0 W + U_r p}{W + p} \right)$

By equating this expression with that already deduced for the accelerating forces, the following general formula results—

$$G g a l \frac{h_1}{l} = l (p + W) \phi \left(\frac{U_0 + W U_r p}{W + p} \right) \quad \ldots\ldots\ldots \quad (1)$$

Dividing both members of the equation by $G g l$, since, for formulæ applying to water, $G g$ may be assumed constant for any moderate change of latitude, and substituting for $\frac{h_1}{l}$ its value s, and for U_0 and U_r their values for ordinary river cross sections, remembering that $0.317 + 0.06 f = \frac{d_1}{r}$, this expression, by reduction, becomes

$$\frac{a s}{W + p} = \phi \left\{ 0.93\ v + (b\ v)^{\frac{1}{2}} \left[\frac{W \left(0.333 - \frac{d_1}{r} \right) + p \left(\frac{d_1}{r} - 0.667 \right)}{W + p} \right] \right\} \quad . \quad (ii)$$

substituting $q\ p$ for W in the fraction of the last term of the second member of equation (ii) it becomes

$$\frac{0{\cdot}333\ q - \frac{d_1}{r} q + \frac{d_1}{r} - 0{\cdot}667}{q + 1}$$

But for rivers, q is never quite, although always very nearly equal to unity: for the Mississippi, its value is about 0.99 No sensible error then can arise from assuming it equal to unity in the above fraction, which thus becomes -0.167

The sign of this quantity must be changed since, in the ultimate value for V, which is a root of an equation of the second degree, the difference between the radical and the other terms is the root of the equation corresponding to the true mean velocity. Without this change of sign, the deduced value of the numerical coefficent will correspond to the other root of the equation, which is the wrong one, since it does not become zero when the slope is zero.

Substituting then the value $+ 0{\cdot}167$, for the fraction in the second member, equation (ii) becomes

$$\frac{a s}{W + p} = \phi \left(0.93\ v + 0.167 b^{\frac{1}{2}} v^{\frac{1}{2}} \right) = \delta z. \ \ldots\ldots \ (iii)$$

It is plain that in making observations for deducing the constants of the new formula, the variables must be accurately measured.

The manner of performing the necessary field work for measuring all except the slope has been mentioned in the previous notice The determination of the true s needs many important considerations. This quantity for rivers is usually stated to be equal to the quotient obtained from the division of the fall of the water surface in a given distance, by the distance.

This is inaccurate language, and has led to many errors in applying the formula. The fall of any natural stream in any considerable distance is consumed in overcoming three entirely distinct resistances; first, that already described as due to the joint action of adhesion and cohesion, second, that arising from the loss of living force when the stream is deflected by bends, and third, that arising from the loss of living force caused by changes in width and depth

The first of these only is taken into account by formulæ whose constants are derived from observations in which the condition of uniform motion is perfectly fulfilled.

If, therefore, such formulæ are applied to rivers, the mean area, width and perimeter between the upper and lower points considered must be used with a slope computed by dividing the actually observed fall between those points (diminished by that expended in overcoming the other two resistances), by the total distance. For that consumed in overcoming the resistances due to changes in cross section, it is clear no practical formulæ can be framed, if for no other reason than that the requisite knowledge of the exact form of the cross section cannot be obtained in practice Formulæ, whose constants correspond to perfect uniformity of motion, then, cannot be applied to rivers.

Hence the constants of river formulæ must be deduced from observations upon natural channels, and not upon pipes and troughs The above considerations then indicate that these conditions should be fulfilled by observations conducted for the purpose of deducing the form of the function composing the second member of equation (III)

First, they should be made on a natural channel. Second, the bed must be straight at the locality to allow for the effects of bends upon the slope. Third, the cross section must be sensibly uniform in order to avoid the effect of sudden variations upon the slope To these it may be added that the distance must be considerable, as great as possible in fact, in order to reduce to a minimum the percentage of instrumental error in

measuring the slope. Even in a locality fulfilling all these conditions, the measurement is an operation of exceeding delicacy.

The water surface even then is by no means a plane, the different velocities at different distances from the bank destroy such character since water in motion exerts less pressure than when at rest. This causes the level of the surface near the thread of the current to rise, in order to maintain the equilibrium. The difference of height due to this cause is usually estimated by the formula $h = \frac{V_1^2 - V^2}{2g}$, thus, the difference of level between the water moving near the bank with a velocity of 1 foot per second, and that on the thread of the current moving at the rate of 8 feet per second is $\frac{8^2 - 1^2}{2g} = 0.98$ feet, or more than 11 inches.

If then the water move with different velocities at the two level stations, error will result.

The air also is seldom still, and even as gentle wind, besides producing oscillations in the surface, may sensibly affect the relative level of the two stations. The almost constant rising and falling of the river greatly increases the liability to error. Add to these and to local causes of variation, such as eddies and boils, the exceedingly small numerical values of the slope for most natural channels, and an idea can be formed of the difficulty of its determination at any particular locality. This measurement was attempted on the Mississippi survey in connection with observations for the discharge.

The area, width and perimeter were found by taking a mean of all the sections at each site, including as one section a mean of those at the velocity base. The mean velocity of observation was obtained by dividing the discharge found at the velocity base by this mean area.

The slope was measured in the following manner :—Bench-marks were erected at convenient sites, and connected by means of a careful level and traverse survey. The levelling was repeated five times to ensure accuracy.

When the slope was to be measured, graduated stakes were placed in the water opposite to them, and carefully referred to the bench-marks by means of the levelling instrument.

Accurate observations of the height of the water surface upon the stakes were then made simultaneously by different observers.

The results are given in the first 18 observations detailed in Table I. (*see* Appendix). The next step was to collect all the reliable observations on

natural streams on record, and to correct the discharges according to the principles laid down in the preceding notice, and to correct the falls for bends, by the bend formula to be afterwards given, these observations form the last twelve experiments in Table II The third, and last step, was to adjust the constant of formula (III) so that it might agree with the results given in this table.

This was done in the following manner, the expression $\phi\, z$ in equation (III) was placed equal to Cz^2, giving, by reduction, the following formulæ

$$C = \frac{a\,s}{z^2\,(p + W)} \quad \ldots \ldots \ldots \ldots \ldots (\text{iv}).$$

The second member containing only known terms, its value was computed for the different observations, and it was at once evident that C could not be assumed to be constant

To detect its law of variation, the different values were plotted as ordinates to the corresponding values of $\frac{a}{p \text{ and } W}$, V_1 and S successively as abscissæ. While serrated curves following no apparent law resulted, when C was plotted with $\frac{a}{p \text{ and } W}$ or V_1, a quite uniform result was obtained by using S. It was then reasonable to conclude that C was some function of this quantity. After several trials it was found that $C = \frac{s^{\frac{1}{2}}}{195}$ would nearly fulfil the necessary condition It was accordingly adopted. When this value of C is substituted in equation (IV) it can be put in the form

$$z = \left(\frac{195 s^{\frac{1}{2}} a}{W + p}\right)^{\frac{1}{2}} \ldots \ldots \ldots \ldots \ldots (\text{iv}).$$

and by reduction, $s = \left(\frac{(p + W)z^2}{195\, a}\right)^2$

$$a = \frac{(p + W)\,z^2}{195 s^{\frac{1}{2}}} \quad (p + W) = \frac{195\, a\, s^{\frac{1}{2}}}{z^2}$$

$$\text{now, } z = 0\cdot93\, v + 0\cdot167 b^{\frac{1}{2}} v^{\frac{1}{2}} \ldots \ldots \ldots \ldots (\text{v})$$

Substituting these values in equations (IV. and V.) and solving with respect to v, we get.

$$v = \left(\sqrt{0\cdot0081\, b + (225 r_1 s^{\frac{1}{2}})^{\frac{1}{2}}} - 0\cdot09\, b^{\frac{1}{2}}\right)^2 . \ldots \ldots (\text{vi}).$$

For small streams, as already shown, b varies with r, being given by the equation $b = \frac{1\cdot69}{\sqrt{r} + 1\cdot5}$

but, for rivers whose mean radius exceeds 12 or 15 feet, b may be assumed $= 0\cdot1856$. This makes the numerical value of the term involving b so small, that for any but theoretically small, velocities it may be neglected, thus reducing equation (VI.) to

$$v = ((225\, r_1\, s^{\frac{1}{2}})^{\frac{1}{4}} - 0{\cdot}0388)^2 \; \ldots \qquad (\text{vii}).$$

Which by reduction gives

$$r_1 = \frac{(\sqrt{v} + 0{\cdot}0388)^4}{225\, \sqrt{s}} \qquad \ldots \qquad (\text{viii})$$

$$s = \left(\frac{(\sqrt{v} + 0{\cdot}0388)^4}{225\, r_1} \right)^2. \qquad \ldots \qquad (\text{ix}).$$

Effects of bends, abrupt inequalities of the channel, &c., upon the fall of a River

When water moving uniformly in a straight channel encounters a bend, the additional power to make a change of direction can only be acquired by an increase of slope, and the water is backed up until this increase is obtained. The fall in the reach above is adjusted to the level at the head of the bend, for a short distance above which, the slope is less than in the straight reach, owing to the accumulation of water.

The effect of every bend is, therefore, like a dam, to elevate permanently the plane of the water surface above it, without affecting that a short distance below.

To estimate the amount of this increased fall, Du Buat assumed an equation of the form $h_{,,} = \dfrac{v^2 \sin^2 a}{\varepsilon}$, where ε is a constant which, from certain experiments on pipes, he found $= 266\ 3$ feet.

In order to deduce a constant applicable to rivers, the writers of the Mississippi report made experiments on a reach of the river containing a straight piece and a bend.

It was reasoned that, if the bend had not existed, the slope measured in the straight part of the river multiplied by the distance between the extreme stations, would give the fall between them.

The difference between this quantity and the observed fall is $h_{,,}$, the fall expended in overcoming the additional resistance due to the bend.

The corresponding values of a were found by plotting a line containing angles of incidence of about 30° upon the transit sheets of the survey near the midchannel. The sum of the squares of the natural sines of these angles gave the numerical value of $\sin^2 a$. In this way, ε for river formula was found to be $= 134$ feet.

Further research showed that $\sin^2 a$ is very nearly equal to 0·34 M, where M is the excess of the distance in miles of the distance by the river, over that by an air line,

Tables I and II show how superior in accuracy the new formula is above, all others, when applied to the data collected by the survey

It is impossible to detail within the limits of this paper the various other tests applied to the formula Suffice it to say, that after comparing the results given by different formulæ for the velocity, the slope was calculated in several instances from the observed velocity and mean radius, and the result found to agree with the observed fall after correction by the bend formula, and lastly, a formula was established on the preceding principle, giving the variation in the height of the river at different points due to variations in the discharge, which was found to accord in an equally satisfactory manner with observation

In conclusion, the compiler would remark, that this formula for the velocity in terms of the cross section and slope would seem to be a natural consequence from the newly discovered fact of the surface resistance to the motion of water in rivers, and the relations between the surface and bottom velocities and the mean velocity of a river established by the experiments of the survey, and that the formula is entitled to weight because it is founded on carefully observed facts, gleaned from measurements on natural channels, and not on pipes and troughs Table II shows that it is equally applicable to the Neva, and other rivers, as well as the Mississippi The data, it is true, are scanty compared with those on which their formulæ for the discharge, obtained by direct measurement, are founded, but as far as they go, they are thoroughly to be relied on, and support fully the correctness of the proposed formula

But in using it the following precautions must be observed —

1 The sections should be taken if possible in a straight reach of the river.

2. They should be as uniform as possible, and their areas nearly equal

3 If the river winds between the sections, the fall must be corrected by the bend formula.

4. The distance between the sections should be as great as possible to eliminate instrumental error.

5 The velocity near the bank must be the same at the different level stations.

6 Observations of fall should be several times repeated (at least three times) to guard against mistakes in measuring so small a quantity.

7 The air should be perfectly still when the observations for fall are made.

It is very seldom that flood marks can be so accurately ascertained in the cold weather in this country, that any approximation to the fall of the flood surface of a river can be safely made from them

In cases when accuracy is required, and the flood marks cannot be relied on in fixing the fall, the writer believes the best and safest plan is to determine the discharge and mean velocity of the river in the rains (when the river is at a high level) from surface or mid depth velocities, and, from the data thus obtained, to calculate the slope of the river by equation (IX) By applying this slope to the cross section of the river at extraordinary flood level, the discharge at this stage of the river can be deduced

When the total rise of high flood level is the same at each section, the fall of the flood surface is the same as that of the cold weather surface.

But even then, the slope often varies slightly at intermediate stages, most at medium stages; indeed the slope may vary for the same gauge reading.

When the total rise of flood surface is different at the extremities of the reach of the river in which the sections are taken, it is evident that still more causes of error would operate to vitiate the perfect accuracy of this method.

These causes of error may to a great extent be eliminated by measuring the discharge when the river is only a few feet below its highest level

The writer believes that a far closer estimate of the greatest known discharge of a river may be made by this method when the flood marks are not perfectly clear and beyond doubt, than by depending, as it too often the case, on the rough statements of villagers.

APPENDIX.

Nomenclature used in the preceding Paper.

l = Length of a limited portion of the river

$h = h_{\prime} + h_{\prime\prime}$ = Difference of level of the water surface at the two extremities of the distance l.

$h_{\prime}$ = The part of h consumed in overcoming the resistance of the channel supposed to be straight and of nearly uniform section.

$h_s =$ The part of h consumed in overcoming the resistances of bends and important irregularities of cross section.

$s = \frac{h_1}{l} =$ The sine of the slope or fall in unity

$a =$ Area of cross section, $p =$ length of wetted perimeter.

$r = \frac{a}{p} =$ Hydraulic mean depth.

$r_{,} = \frac{a}{p + W} =$ Mean radius.

$v =$ Mean velocity of river.

$d_{,} =$ Depth below the surface of the fillet moving with maximum velocity

$W =$ Width of river surface at any particular locality

$U_o =$ The grand mean of the surface velocities in all vertical planes parallel to the current between the banks, found to be nearly equal to

$$0·93\ v + (0·016 - 0·06\,f)\,(b\ v)^{\frac{1}{2}}.$$

$U_r =$ The grand mean of all bottom velocities—

$$= 0·93\,v\ (0·06\,f - 0·350)\,(b\ v)^{\frac{1}{2}}$$

$\alpha =$ Angle of incidence of the water passing round a bend. It is always assumed equal to 30°, and the effect of the bend estimated by determining the number of such deflections necessary to pass round it.

$G =$ Density of river water.

$g =$ The velocity acquired in falling 1 foot $= 32·138$ feet its value in latitude 35°.

(*For the remaining nomenclature*, see No. CLXXXVII., Professional Papers.)

OLD FORMULÆ FOR THE DISCHARGE OF RIVERS TESTED ON THE MISSISSIPPI SURVEY.

Chezy's,
- Young's coefficient, $v = 84·3 \sqrt{r\ s}$
- Eytelwein's ,, $v = 93·4 \sqrt{r\ s}$
- Downing's, and others, $v = 100 \sqrt{r\ s}$

$$\text{Du Buat's, } v = \frac{88·49\ (r^{\frac{1}{2}} - 0·03)}{\left(\frac{1}{s}\right)^{\frac{1}{2}} - \mathrm{L}\left(\frac{1}{s} + 1·6\right)^{\frac{1}{2}}} - 0·086\ (r^{\frac{1}{2}} - 0·03).$$

In which L = common log × 2·302585

$$\text{Girard's, } v = (2·69 + 26384\ s\ r)^{\frac{1}{2}} - 1·64$$

$$\text{De Prony's,}\begin{cases}\text{For canals,} & v = (0.0556 + 10593\,rs)^{\frac{1}{2}} - 0.2357\\ \text{For canals and pipes,} & v = (0.0237 + 9966\,rs)^{\frac{1}{2}} - 0.1542\\ \text{Eytelwein's coefficient,} & v = (0.0119 + 8963\,rs)^{\frac{1}{2}} - 0.1089\\ \text{Weisbach's} \quad ,, & v = (0.00024 + 8675\,rs)^{\frac{1}{2}} - 0.0154\end{cases}$$

$$\text{Young's, } v = \left(\frac{r\,s}{3\,A} + \left(\frac{B}{12\,A}\right)^2\right)^{\frac{1}{2}} - \frac{B}{12\,A}$$

$$\text{In which } A = 0.0000001 \begin{bmatrix} 413 + \frac{1.5625}{r} - \frac{90}{3r+8} \\ - \frac{15}{4\,r + 0.0296}\end{bmatrix}$$

$$\text{And } B = 0.0000001 \left(\frac{900r^2}{r^2+0.50} + \frac{1}{(3\,r)^{\frac{1}{2}}}\left(271.25 + \frac{6.88}{r} + \frac{0.0001146}{r^2}\right)\right)$$

$$\text{Dupuit's, } v = \frac{s\,r\,a}{0.08\,W} + (0.0067 + 9114\,r\,s)^{\frac{1}{2}} - 0.082$$

$$\text{St Venant's, } v = 106.068\,(r\,s)^{\frac{11}{21}}$$

$$\text{Ellet's, } v = 0.64\,(\Delta\,H)^{\frac{1}{2}} + 0.04\,\Delta\,H)$$

In which Δ denotes the maximum depth of the stream, and H the fall in water surface in one English mile

KISHNAGHUR,
December, 1868

A J H

TABLE No. I Measurement of cross section, slope, and resulting mean velocity of rivers.

No of observation	Stream	Date	Dimensions of cross section				Mean velocity.	Slope	Authority.
			Area	Width	Perimeter	Maximum depth			
1	Mississippi, .	H W. '51	193,968	2653	2693	136	5·9228	0·00002051	Delta survey.
2	,, .	,,	195,349	2656	2696	136	5·8869	0·00001713	,,
3	,, ..	,,	180,968	2421	2461	131	4·0338	0·00000342	,,
4	,, ..	1858	183,663	2429	2469	132	3·9775	0·00000384	,,
5	,,	,,	148,042	2211	2247	88	6·9575	0·000068	
6	,, ..	,,	178,187	2729	2779	100	6·9496	0·00006379	,,
7	,, ...	,,	179,502	2732	2782	101	6·8245	0·00004365	,,
8	,, ..	,,	78,828	2507	2530	63	3·5234	0·00002227	
9	,,	,,	134,942	2556	2589	83	5·5580	0·00003029	
10	,,	,,	150,354	2580	2621	90	6·3180	0·00004811	
11	Bayou Plaquemine, .	1851	5,560	292	303	28	5·1979	0·00020644	Mr Ellet
12	,,	1859	4,259	268	278	24	3·0589	0·00014372	Delta survey.
13	Bayou La Fourche, ..	1851	3,738	223	238	27	3·0765	0·00004468	,,
14	,, ..	,,	3,025	223	232	24	2·8430	0·0000373	,,
15	,, ..	,,	2,957	223	231	24	2·8069	0·00003655	,,
16	,, ..	,,	2,868	223	230	23	2·7894	0·00004384	,,
17	C. and O Canal Feeder, ..	1859	121	23	32·7	7·6	3·0323	0·00069851	,,
18	,, .	,,	119	23	32·5	7·5	2·7227	0·00069851	,,
19	Ohio River, ..	1858	7,218	1073	1074	8	2·5152	0·00009334	Mr Ellet
20	Haine, France,	1782	248·5	48	50·5	8?	2·1947	0·00016534	M Du Buat.
21	,, .	,,	306·4	50·5	53·1	9?	2·5579	0·00015593	,,
22	Canal, England,	..	50	18	20·6	4	1·1336	0·00006313	Mr Watt
23	Rhine, .	1812	19,135	1155	1163	20	3·5749	0·00009769	M Kragenoff.
24	,, ...	,,	6,304	557	563	17?	3·2766	0·00009986	,,
25	Waal, ..	,,	11,782	1328	1334	17?	3·1648	0·00010438	,,
26	Rhine,	,,	5,341	700	704	12?	2·9167	0·00011744	,,
27	Yssel, .	,,	1,930	321	324	9?	2·7727	0·00011657	,,
28	Tiber, .	1821	2,855	243	249	15	3·4132	0·00013061	M Buffon
29	Neva, ..	18—	43,461	1218	1227	50	3·2296	0·00001389	M Destelm.
30	Great Nevka, ...	,,	15,554	881	893	21	2·0486	0·00001487	,,

TABLE II.—Tests of the various Formulæ for Mean Velocity.

	Chezy's formula with coefficient of			DuBuat's formula.	Girard's formula	De Prony's formula with coefficient				Young's formula.	Dupuit's formula	St Venant's formula.	Ellet's formula	New formula.
	Young	Eytelwein	Downing and others			For canals.	For pipes and canals	By Eytelwein	By Weisbach					
1	+ 2.6888	+ 2.3390	+ 2.0854	+ 3.1820	+ 1.1140	+ 2.2017	+ 2.243	+ 2.3974	+ 2.3644	+ 2.6547	+ 1.0536	+ 2.4381	+ 2.8837	+ 0.0385
2	+ 2.9167	+ 2.5961	+ 2.3636	+ 3.4374	+ 1.5736	+ 2.4887	+ 2.5204	+ 2.6584	+ 2.6206	+ 2.9000	+ 1.4629	+ 2.7002	+ 3.1500	+ 0.2425
3	+ 2.6973	+ 2.5530	+ 2.4484	+ 3.3542	+ 2.6207	+ 2.6208	+ 2.5978	+ 2.6378	+ 2.5725	+ 2.7822	+ 2.3651	+ 2.6534	+ 2.9552	+ 0.2593
4	+ 2.5522	+ 2.3984	+ 2.2868	+ 3.2073	+ 2.4188	+ 2.4572	+ 2.4369	+ 2.4820	+ 2.4182	+ 2.6320	+ 2.1732	+ 2.5009	+ 2.8230	+ 0.0658
5	+ 1.3152	+ 0.7061	+ 0.2643	+ 1.5090	− 2.3975	+ 0.3004	+ 0.4281	+ 0.7288	+ 0.7388	+ 1.1238	− 3.0950	+ 0.7159	+ 2.0962	− 0.8093
6	+ 1.5591	+ 0.9772	+ 0.5552	+ 2.7722	− 1.9246	+ 0.5998	+ 0.7184	+ 1.0038	+ 1.0091	+ 1.3844	− 0.0954	+ 0.9996	+ 1.8853	− 0.4602
7	+ 2.3506	+ 1.8677	+ 1.5174	+ 2.6733	− 0.3106	+ 1.5929	+ 1.6784	+ 1.9078	+ 1.8968	+ 2.2359	− 0.4739	+ 1.9298	+ 2.8054	+ 0.0713
8	+ 1.3028	+ 0.0631	+ 0.8893	+ 1.6224	+ 0.5812	+ 1.0377	+ 1.0434	+ 1.1361	+ 1.0853	+ 1.3343	+ 0.8166	+ 1.1737	+ 1.4852	− 0.3978
9	+ 2.2085	+ 1.8469	+ 1.5817	+ 2.5718	+ 0.5389	+ 1.6975	+ 1.7427	+ 1.9037	+ 1.8726	+ 2.1690	+ 0.8041	+ 1.9437	+ 2.6953	+ 0.0430
10	+ 1.8902	+ 1.4121	+ 1.0654	+ 2.1721	− 0.7304	+ 1.1425	+ 1.2263	+ 1.4580	+ 1.4411	+ 1.7785	− 0.6254	+ 2.0143	+ 2.3442	− 0.1982
11	+ 0.0094	− 0.5507	− 0.9569	− 0.1965	− 3.2932	− 0.9055	− 0.7942	− 0.5211	− 0.5194	− 0.1556	− 1.4981	− 0.5187	+ 0.4408	− 0.0448
12	+ 0.0033	− 0.4288	− 0.7334	− 0.0583	− 2.1974	− 0.6407	− 0.5738	− 0.3760	− 0.3963	− 0.0801	− 0.8769	− 0.3435	+ 0.4993	− 0.3871
13	+ 0.8434	+ 0.6023	+ 0.4275	+ 1.0077	+ 0.1116	+ 0.5756	+ 0.5817	+ 0.6751	+ 0.6245	+ 0.8751	+ 0.4812	+ 0.7129	+ 1.2065	− 0.2076
14	+ 0.9837	+ 0.7829	+ 0.6374	+ 1.1533	+ 0.5428	+ 0.7964	+ 0.7900	+ 0.8069	+ 0.8040	+ 1.0392	+ 0.7353	+ 0.8921	+ 1.2623	+ 0.0213
15	+ 0.9835	+ 0.7866	+ 0.6439	+ 1.1535	+ 0.5695	+ 0.8039	+ 0.7963	+ 0.8651	+ 0.8076	+ 1.0613	+ 0.7447	+ 0.8954	+ 1.2442	+ 0.0304
16	+ 0.8184	+ 0.6056	+ 0.4513	+ 0.9686	+ 0.2926	+ 0.6072	+ 0.6044	+ 0.6821	+ 0.7270	+ 0.8657	+ 0.5499	+ 0.7156	+ 1.0997	− 0.0768
17	− 1.2535	− 1.7162	− 2.0517	− 1.7040	− 3.7470	− 1.9699	− 1.8912	− 1.6733	− 1.6876	− 1.3746	− 1.9100	− 1.6470	− 1.4773	− 0.0709
18	− 1.5406	− 2.0068	− 2.3346	− 1.9857	[illegible] 4.0141	− 2.2520	− 2.1741	− 1.9576	− 1.9723	− 1.6603	− 2.1895	− 1.8953	− 1.7497	− 0.3594
19	+ 0.4038	+ 0.1759	+ 0.0106	+ 0.6998	− 0.2313	+ 0.1623	+ 0.1643	+ 0.2504	+ 0.1977	+ 0.4406	+ 0.1520	+ 0.2864	+ 1.0867	+ 0.0298
20	+ 0.0901	− 0.1694	− 0.3577	+ 0.0453	− 0.7802	− 0.2148	− 0.2028	− 0.0990	− 0.1467	+ 0.1054	− 0.2003	− 0.0593	+ 0.5240	+ 0.0257
21	+ 0.0364	− 0.2358	− 0.4333	− 0.0038	− 0.9301	− 0.2940	− 0.2779	− 0.1671	− 0.2128	+ 0.0447	− 0.2847	− 0.1265	+ 0.5194	− 0.0866
22	+ 0.0901	− 0.0226	− 0.1043	+ 0.1478	− 0.1788	+ 0.0737	+ 0.0425	+ 0.0655	− 0.0040	+ 0.1871	+ 0.0257	+ 0.0684	+ 0.3413	− 0.1965
23	+ 0.1952	− 0.1696	− 0.4342	+ 0.2315	− 1.5005	− 0.3224	− 0.2761	− 0.1133	− 0.1439	+ 0.1506	− 0.5043	− 0.0736	+ 1.1067	− 0.4809
24	+ 0.4577	+ 0.1534	− 0.0673	+ 0.4877	− 0.7571	+ 0.0627	+ 0.0891	+ 0.2179	+ 0.1774	+ 0.4492	+ 0.0070	+ 0.2597	+ 1.0020	− 0.0544
25	+ 0.2978	− 0.0117	− 0.2361	+ 0.2478	− 0.9577	− 0.1078	− 0.0797	+ 0.0520	+ 0.0125	+ 0.2862	− 0.1620	+ 0.2895	+ 0.8310	− 0.1808
26	+ 0.4004	+ 0.1288	− 0.0682	+ 0.4037	+ 0.5617	+ 0.0712	+ 0.0871	+ 0.1976	+ 0.1518	+ 0.4107	+ 0.0629	+ 0.2382	+ 0.8733	+ 0.0973
27	+ 0.5513	+ 0.3115	+ 0.1376	+ 0.5584	− 0.1711	+ 0.2860	+ 0.2918	+ 0.3845	+ 0.3337	+ 0.5803	+ 0.2855	+ 0.4221	+ 1.0048	+ 0.2993
28	+ 0.4503	+ 0.1305	− 0.1015	+ 0.4294	− 0.8867	+ 0.0238	+ 0.0553	+ 0.1928	+ 0.1587	+ 0.4315	− 0.0107	+ 0.2347	+ 0.9410	+ 0.1378
29	+ 1.3598	+ 1.1579	+ 1.0115	+ 1.4974	+ 0.9109	+ 1.1702	+ 1.1641	+ 1.2357	+ 1.1790	+ 0.4133	+ 0.9731	+ 1.2671	+ 1.8573	− 0.4976
30	+ 0.6919	+ 0.5455	+ 0.4393	+ 0.9601	+ 0.6026	+ 0.6112	+ 0.5888	+ 0.6300	+ 0.5649	+ 0.7771	+ 0.5348	+ 0.6463	+ 1.1609	− 0.5191
Totals,	32.9420	28.4411	26.6988	40.4417	37.4472	28.0905	28.1506	29.5255	28.8412	33.3834	25.1488	30.6619	45.3547	6.3920

Note.—This table exhibits the result of the test. The figures denote the amount of the *discrepancies*, and the signs denote the manner in which they are to be applied to the computed mean velocity in order to reduce them to those given in the preceding Table. Thus, under the first observation, the error by the Du Buat formula being + 3.1820, the computed mean velocity is 2.7468 feet, since 2.7468 + 3.1820 = 5.9288 feet, the measured mean velocity.

No. CCXIX.

CIRCULAR BRICK CLAMPS

THIS kind of clamp, although largely used in various parts of the country, has never been described in print, so far as the writer is aware, and it is hoped that the following memorandum on the subject may prove useful to officers who have had no experience in brick burning with *oopla*,* and that officers who have been successful with such clamps may be induced to publish their experience, particularly with reference to the thickness given to the layers of fuel Clamps will be found superior to native *pujawahs* in percentage of first-class outturn, and a very great advantage in their use is, that the exact quantity of bricks and fuel loaded into the clamp can be determined by measurement, which cannot be done in the case of *pujawahs*, where the officer in charge is almost entirely at the mercy of his mates and moonshees with regard to the expenditure of fuel.

Clamps can only be used when *oopla* is obtainable in large quantities, where *koora*† is chiefly procurable, pujawahs should be used. A clamp containing a lakh and three-quarters of 9-inch bricks should be about 64 feet in diameter in the lowest course of bricks, and ought to take 14 days to load, 14 days to burn out, and a month to cool down. The thicknesses of fuel given on the drawing are those which should be used in the hot weather, but, at the commencement of operations in the cold season, the thickness of oopla in the courses should be increased by about 20 per cent. The average outturn through the season, if care is taken to regulate thickness of fuel properly, should be about 70 per cent. first-class, and 10 per cent. second-class, bricks, per 100 kutcha bricks

* Cakes of dried cowdung, also called *kunda*. † *Koora*, stable litter or village refuse.

loaded. The following memorandum was adapted and modified from one in use in the Jullundur Division —

Memorandum for guidance of Subordinate in charge of Kiln-yard, in loading Circular Clamp.

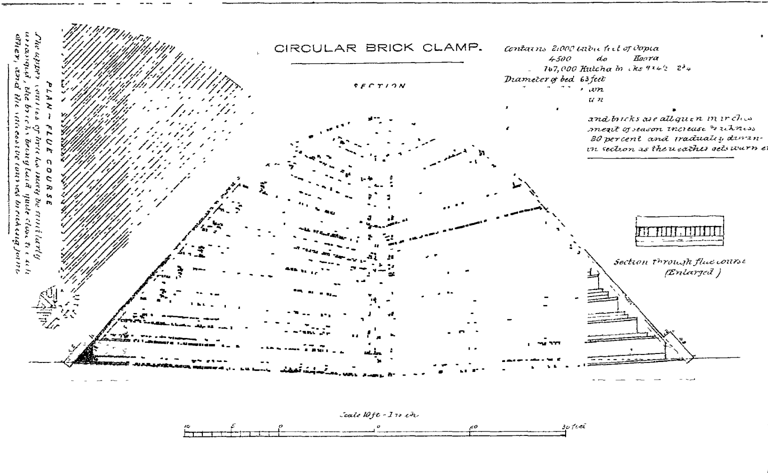
1. Prepare the ground by describing a circle about 64 feet in diameter, and form the ground into a neat and regular inverted cone, depth of which may be about 18 to 24 inches. Spread a bed of ashes over this, if available; if not available, use 3 inches of *koora.*

2. Loading is not to commence until the bricks and fuel required for the clamp have been all collected at site.

3. Commence the clamp by a course of brick-on-edge (ṗeela 12-inch bricks if available) arranged as shown in plan of flue course. This course forms a succession of flues into the heart of the clamp, and allows the fire to spread regularly from centre to circumference in the lowest course of fuel.

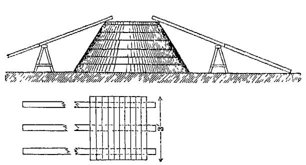
4. Lay on the flue courses, a course of *oopla* of equal thickness packed regularly; when completed, beat this down slightly with wooden beaters and spread over all about 2 inches of koora. No other fuel than oopla and koora is to be used in any part of the clamp. Koora is infused to prevent the oopla burning too rapidly.

5. On this lay a course of brick-on-edge, then a second course of oopla and koora, as shown in the drawing, and so on, beating down each course of oopla before the koora is laid on it, the beating to be harder and continued longer in the higher, than in the lower, courses. The surface of each coat of koora is to be formed into a neat inverted cone before laying the bricks over it. It is a standing rule that each course of fuel and bricks must be measured by the subordinate in charge before the next course is laid, and the actual measurements are to be rendered by him in the register, whatever they may be. The thickness of the oopla is to be measured after it is packed and before it is beaten down, and is always to be recorded in *inches.* Small pillars of kutcha bricks are to be built to the proper height, at intervals, round the circumference of each layer of bricks, as a guide to the workmen in packing the oopla, and the subordinate in charge must satisfy himself that these pillars are correctly gauged before the oopla is laid. When the


CIRCULAR BRICK CLAMP.
SECTION
Contains 2,000 cubic feet of Oopla
4500 do Koora
167,000 Kutcha bricks 9×4½ 2¾
Diameter of bed 63 feet
and bricks are all given in inches
ment of season increase thickness
20 percent and gradually diminish
in section as the weather gets warmer
Section through flue course (Enlarged)
Scale 10 ft - 1 inch
10 5 0 10 20 30 feet
PLAN – FLUE COURSE
The upper courses of bricks may be similarly arranged, the bricks being laid quite close to each other, and the successive courses breaking joint

fuel is laid, the pillars are to be removed and their place filled up with oopla The bricks are to be laid as close together on edge as possible, and it is not necessary to leave any openings between them, as the fire spreads with sufficient rapidity when the bricks are laid close. The outer rings of the courses of bricks should be of peela bricks, if any are available, as they will probably burn pucka and become useful Care must be taken to leave a vertical flue of about 12 inches diameter in centre of the clamp, through which the kiln is to be fired; it is to be kept covered by an inverted *gurrah* as the work goes on, and is to be cleared by pushing down a long bamboo before lighting the clamp, which is effected by dropping live charcoal down the flues, and when the fire has taken, this flue is to be closed.

6 In loading the clamp, the coolies are not to be allowed to make ramps of oopla to reach the top, as they will do if not prevented, temporary bridges should be formed of two or three stout bullies, 18 to 20 feet long, laid about 18 inches apart, and covered with bamboos lashed or nailed on. Four of these will be required for each kiln in pro-



gress. The marginal sketches will explain their construction and use. One pair of bridges is required for coolies carrying up loads to the upper courses and one for those returning; they are supported on stout trestles of proper height, the bridges and trestles being shifted as each course is completed.

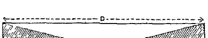
7. The outer surface is to be smoothed off with oopla, the steps left being filled up, commencing from the top, and a course of cakes of oopla packed on edge laid over this. The whole is to be finished off with a

coat of 3 inches of koora covered with ashes, and a straw covering and leeping are unnecessary. When the outer coat is completed, a kutcha wall of refuse bricks in mud is to be built up all round the clamp to a height of 4 feet or so, flues communicating with the flue course being left all round, which are to be closed when it is found that the clamp is burning properly, and are to be opened when required to regulate the spread of the fire.

8. As the burning goes on, any openings which may form are to be closed at once with oopla, koora and ashes, and a party of coolies must be kept at this work night and day for the first few days after lighting the kiln. If the diameters of the courses of bricks are made to diminish 4 feet in each course up to the 8th, and 6 feet in the courses above the 8th, little trouble will be experienced in the above respect, and the courses should also be stepped off as shown in the drawing, but if these points be not attended to, great trouble and loss will be caused by bricks falling down the sides as the clamp settles. If fire breaks out, it should be at once smothered with ashes

9. Unloading may be commenced so soon as the clamp cools down, but care must be taken not to open it prematurely, as if opened before the bricks have become annealed, great breakage will certainly take place in the process of unloading, and the bricks will be rendered brittle.

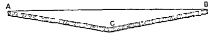
10. Clamps are to be unloaded from the top downwards in successive courses as loaded, and the state of each course is to be recorded in the register by the subordinate in charge, for guidance in regulating the thickness of fuel in future clamps. The ashes are to be regularly removed from each course in baskets, and used in forming a bed for a new kiln or in filling excavations.



Measurements of courses of fuel, &c —To find cubic feet of oopla in any course.—Measure diameter D in feet with a tight tape, and measure H and h in inches. Then, cubic feet oopla $= \frac{\text{area square feet}}{18} \times (H + \frac{1}{3} h)$

or, by common slide rule $\left\{ \begin{array}{lll} C & \overset{\text{Answer}}{\text{Content cubic feet.}} & H + \frac{1}{3} h \\ \hline D & \text{D in feet.......} & .479 \text{ or } 1\,514 \end{array} \right.$

To find cubic feet of koora in any course.—Measure diameter $AB = D$ with a tight tape, sides of cone $ACB = D_1$ with a loose tape, measure the thickness in inches $= h$, use a new diameter $= \sqrt{D \times D_1}$ and find area of circle to this diameter



Then, content of course in cubic feet $= \dfrac{\text{area of circle}}{12} \times h$.

$$\text{or, by slide rule} \left\{ \begin{array}{lll} C & \overset{\text{Answer}}{\text{Content cubic feet}} & h \\ \hline D & D \text{ or } \sqrt{DD} & 1{\cdot}236 \text{ or } 3{\cdot}91 \end{array} \right.$$

To find 9-inch bricks in any course.—Take measurements as for courses of koora, being careful to take the mean measurement where steps are given on the exterior circumference of course of bricks

Then—

$$\left.\begin{array}{c}\text{Content of course}\\ \text{in 9-inch bricks}\end{array}\right\} = \left\{\begin{array}{c}\text{area of}\\ \text{circle}\end{array}\right\} \times 1{\cdot}165 \times h''$$

the constant 1·165 will vary according to the closeness or otherwise of packing of the course, and also according to the size of mould used, and should be determined by counting the bricks actually laid in a sector of some selected course

$$\text{or, by slide rule} \left\{ \begin{array}{lll} C & \overset{\text{Answer}}{\text{Content 9 inch bricks}} & h'' \\ \hline D & D \text{ or } \sqrt{DD_1} & 33042 \text{ or } 1{\cdot}0445 \end{array} \right.$$

h'' is not obtained in this case from actual measurement, but by allowing $4\frac{1}{2}$ inches for each course of brick-on-edge.

The mode of obtaining contents of top and of exterior covering is sufficiently obvious, and it is hardly necessary to remark that the officer in charge can check his subordinate's measurements, by girthing any selected course before the outer covering is laid in. The slide rule will give $\sqrt{DD_1}$, thus,

$$\left\{ \begin{array}{llll} C & D & \text{——} & D_1 \\ \hline D & D & \text{——} & \underset{\text{Answer}}{\sqrt{DD_1}} \end{array} \right.$$

It is recommended that a slide rule should be used for working out the content of the courses, it will be found much more rapid in use than a table of areas of circles and will give contents with sufficient accuracy for all practical purposes. The content of courses, &c., in the accompanying register were all taken out by the slide rule in about five minutes.

W. H. M.

CIRCULAR CLAMP—No. 60—SEASON, 1869-70

Loading commenced 1st April, by Gulzar. Fired, 15th April. Unloading commenced 1st June. Outturn taken on stock, 10th June.

DETAIL OF FUEL.											DETAIL OF BRICKS.							
Measurement of Fuel.								Fuel taken over, and charged off to Clamps in day-book.			Measurement of bricks				Charged off to Clamp in day-book			
Number of course	Thickness of Oopla, inches. Outer H.	Inner h.	Mean $\frac{H+h}{2}$	Thickness of Koora, inches.	Diameter of course, feet	Cubic feet Oopla.	Cubic feet Koora.	Date.	Oopla.	Koora	Number of course	Thickness, inches	Diameter, feet	Content 9″ bricks	Date	Bricks 9″ Kutcha.	Bricks 9″ Pucca	Bricks 12″ Pucca
Flue			3	3	63		800	March 15	3,000		Flue	6	60	9,900				
1	18	18	27	2	60	4,220	472	,, 17	5,000		1	4½	56	12 950				
2	18	14	25	2	54	3,160	382	,, 19	4,000	500	2	9	52	22,300				
3	16	10	21	2	50	2,270	327	,, 21	6,500	1,000	3	13½	48	28,500				
4	16	10	21	2	46	1,925	401	,, 23	3,500	1 000	4	13½	44	24 000				
5	16	7	19½	2	42	1,495	231	,, 24		2,000	5	13½	40	19,500				
6	16	7	19½	2	38-9	1,225	195				6	13½	36-7	16,500				
7	16	7	19½	2	34-5	980	151				7	13½	32-4	13,500				
8	16	7	19½	2	30-1	763	126				8	13½	28-0	10,430				
9	16	10	21	2	25-6	570	85				9	13½	23-3	6 270				
10	16	10	21	2	19½	328	50				10	9	16-7	2,250				
11	16	16	24	2	15	176	24				11	9	10-1	910				
Top G = 34 6 h = 35″						95												
Outer covering $\left.\right\} \frac{184+83}{2} \times 23 \times \left\{\begin{matrix}3'' \text{ Koora} \\ 8'' \text{ Oopla}\end{matrix}\right.$						2,047	1,055											
,, $\left\{\frac{83}{2} \times 15 \times \left\{\begin{matrix}3'' \text{ Koora} \\ 8'' \text{ Oopla}\end{matrix}\right.\right.$						415	155											
Total,						19,669	4,464		21,000	4,500				1,97,010	April 15	1,55,000	7 000	5,600
Add loss in loading,						1,331	36											
Charged in accounts for April,						21,000	4,500											

Outturn and remarks

Expenditure of fuel per 1000 bricks loaded, Oopla, 126 c ft. Koora, 27 c ft.

Outturn			Per cent
Bricks 9″,	1st class,	1,13 500	= 70
,,	2nd,	16,200	= 10
,,	Pucca,	13 100	= 8
,,	Jhama,	13 [illegible]00	= 8
,,	Rubbish,	5,600	= 4
	Total,	1 62 000	= 100
Bricks 12″,	1st class,	4,000	
Brick bats,		1,600	
	Total,	5 600	

The centres of 4th 5th, and 6th course round flue to a distance of 6 feet ran into Jhama. The upper layer of 11th course Pucca, as well as bricks on out side of all courses on the west side.

Note —The above details have not been taken from any clamp actually loaded, the outturn shown is the probable average result for a season's operations

The formula given for finding content of a course in 9-inch bricks reads thus —Set thickness in inches taken on slide, against 33 on the lower line (or against 1 045 as may be most convenient), and against the diameter in feet on the lower line, the contents in bricks will be found on the slide Take, for example, the 6th course of bricks in register Thickness is $13\frac{1}{2}$ inches, diameter with tight tape is 36 feet and with a loose tape 37 feet, the mean diameter being $\sqrt{DD_1} = 36\frac{1}{2}$, as nearly as possible Then take *any* slide rule with C and D lines (all common 2-foot rules with slides have them), set $13\frac{1}{2}$ on the slide against 33 on the lower (D) line, and against $36\frac{1}{2}$ on lower line the number 167 is found This is read as 16,700 If the subordinate in charge is unacquainted with the use of the slide rule, he should be provided with a set of tables, as the labor of calculating out the content of the courses with pen and ink would be very great, and in fact would be impracticable if the operations were carried out on a large scale

The form of register appended will be found very useful The subordinate in charge should be provided with a blank book of such registers ruled out on stout foolscap, and interleaved with common paper for rough notes for use on the works, and this book should be written up by him and sent to office daily for check and transcription, into fair office copy. If this register be kept up regularly, the exact state of the manufacture can always be ascertained at a moment's notice, and the value of materials in kilns readily determined when required, and the rates on each kiln struck if necessary The loss in loading runs an average of 5 per cent, *i. e*, 100 cubic feet oopla brought in stacks packs into 95 cubic feet in the clamp

20th January, 1869.

W H. M.

No CCXX

SUEZ CANAL DREDGERS.

On the Steam Dredgers employed in the Excavation of the Isthmus of Suez Canal. BY M. BOREL, *of Paris* *Abridged from the Proceedings of the Institution of Mechanical Engineers for June* 1867.

THE excavation of the Suez Canal is not of the same character throughout, the general configuration of the Isthmus requiring, at one part, cuttings of considerable depth, but the greater portion of the length requires only the excavation of a channel through ground scarcely above the sea level, and a considerable portion lies below that level so as to require embanking on each side of the channel. A general plan and section of the entire Canal is shown in *Figs* 1 and 2. The present distance from the Mediterranean to the Red Sea across the Isthmus of Suez is 100 miles, but at a comparatively recent date the waters of the Mediterranean reached up the table-land of El Ferdane, and the Red Sea nearly to Chalouf. The land distance of 56 miles between these places was further reduced by Lake Timsah, which was formerly fed by the waters of the Nile, having a bottom 19 feet below the sea level; and also by the two Bitter Lakes, which are 12½ and 9 miles in length, and 16 to 32 feet depth below the sea level, but are at the present time dry. The Mediterranean thus appears to have retreated about 37 miles, leaving behind it the shallow lakes or rather marshes of Lake Ballah and Lake Menzaleh, from the latter of which it is now separated by a narrow

belt of sand of only 100 to 200 yards width The Red Sea has also retreated about 9 miles, leaving a plain at nearly the level of high tide

The first half of the entire length of the canal, extending from the Mediterranean to near the Bitter Lakes, passes mostly through fine sand more or less muddy, some portions passing through clay and mud of varying hardness and consistency, and some through agglomerated sand, but no portion offers serious difficulty to the dredger when excavating from underneath. There are also some beds of calcareous and gypseous formation more or less hard, but not very thick, and not expected to cause any great difficulty to a dredger with the ordinary buckets Near the Bitter Lakes, the soil changes entirely and becomes clayey, and a gypseous clay with a few alternations of sand forms the remainder of the distance to be traversed by the canal to the Red Sea, but this material is not expected to offer any remarkable difficulties to working by a dredger suitably constructed

The canal starts from a point at Port Said on the Mediterranean coast, *Fig* 1, where the water deepens most rapidly, in order to reduce the length of the jetties that have to be constructed The line of the canal passes through the successive lakes, cuts through the elevated table-lands of El Guisr or Ferdane and Serapeum, and the high ground at Chalouf, and crosses the Suez plain to the Red Sea at Suez The section of the canal was originally intended to be made with 26 feet depth of water and 72 feet width at the bottom of the excavation, with slopes of 1 in 2, giving a width of water-way of 176 feet at the surface; but this width has been increased to 328 feet for the portions of the canal passing through the low ground and lakes, as shown in *Fig* 3, and the slopes below the water line have been left to take the natural slope of the soil. For the cuttings through the high ground at El Guisr, Serapeum, and Chalouf, the section of the canal is that shown in *Fig* 4

The first operation consisted in cutting a freshwater canal, in prolongation of the old Ouady Canal from the Nile, for the purpose of obtaining a supply of fresh water for the men employed on the works; this prolongation was carried to Ismailia, where the head quarters of the works are established near the middle point of the maritime canal. The line of the maritime canal through Lakes Menzaleh and Ballah was then commenced by excavating two side trenches, the spoil forming a continuous embankment along each side of the canal across the ground lying

below the sea level, and the embankment on the African side was made strong enough to resist the action of the waves in the lake, and to carry the freshwater conduit on the top. A communication by water was then effected from the Mediterranean to the Red Sea by means of the fresh-water canal, a branch of which was constructed from Ismailia to Suez, as shown in *Fig.* 1, and the channel, though shallow, sufficed for supplying the works, as long as hand labor alone was used. When the fellahs previously employed were withdrawn by the Egyptian Government, mechanical means had to be resorted to for continuing the works, and steam dredgers were then adopted.

The Dredgers used on the first 10 miles of the canal from Port Said are constructed entirely of iron, with one bucket frame, the foot of which is ahead of the hull, so as to be able to open the channel in advance of the vessel. The buckets hold 14 cubic feet each, and the shoots depositing the spoil on the sides of the canal are successively lengthened, the slope of the shoots being about 1 in 10, the wet mud and sand readily pass down them. All the movements for raising and lowering the bucket frame, for traversing across the canal, and for going ahead, &c., are performed by a condensing steam engine of 35 horse power with two cylinders.

On the next portion of the canal, extending to El Ferdane, the surface of the ground is somewhat higher than in the first portion, whereby not merely is the size of the spoil banks increased, but also the height at which the spoil has to be deposited; moreover the clay which here constitutes a portion of the spoil prevents it from spreading so far on falling from the shoot, and thereby further increases the height of the spoil bank. The mode of executing the work, therefore, on this portion of the canal was as follows. Leaving the trench on the African side for the boats bringing up supplies from the sea at Port Said, the Asiatic trench, which as a rule was originally cut narrower and shallower than the other, was enlarged first. All the soil above the water level was taken out by hand labor, and carried beyond the distance at which the dredgers were to deliver, in order to allow as much slope as possible for the dredger shoots, but notwithstanding this precaution, the shoots had still to be lengthened and sloped more gently than before. The dredgers employed for excavating below the water level are worked by engines of 14 to 18 horse power, at high pressure without condensers, having driving belts

id cog wheels driving the tumblers. The hulls, which are of iron, are ? and 82 feet long with 23 feet beam. In order to add to their stability ith their long shoots, a wooden lighter 39 feet long by 10 feet beam as firmly lashed alongside The buckets of those dredgers are from ½ to 5½ cubic feet in capacity, as shown in *Figs* 7 and 8, and the elivery is at the rate of about 20 buckets per minute The shoots are ade of sheet iron, they are 4 feet wide, their cross section being a emi-ellipse with the long axis horizontal, and they are inclined from 1 12 to 1 in 16, their length being from 65 to 72 feet Sixteen of iese dredgers have been used to make 18 miles of new channel, 59 to 5 feet wide and from 6 to 10 feet deep

That portion of the spoil from the main channel of the canal which is ot deposited upon the banks by the dredger shoots is delivered into bal-st-lighters fitted to go out to sea, which discharge the spoil in deep ater in the Mediterranean. The English sea-going ballast-lighters old 217 cubic yards, and have one screw driven by an engine of 50 orse power working with surface condensers, these are excellent boats, oth in form and construction, and also from the simplicity of the whole rrangement Others, built in France carry 261 cubic yards, and work t high pressure without condensing. The speed in both cases is about to 8 miles per hour

In the course of working, it was remarked that by the passage of the essels, and especially of the small steam tugs, the sides of the canal ere worn down somewhat rapidly when dressed to a slope of 1 in 2, and was therefore proposed that the slopes should be pitched, but before his could be accomplished, it was found that the action of the waves had ormed a sort of gently shelving beach, on which their force was then pent without further injury to the slopes This clearly showed that all hat was necessary for the further protection of the slopes was to shift ack the spoil banks AA to such a distance, as shown in *Fig* 3, that ot only might the slopes of the channel of the canal be made flatter with-ut causing the sides and spoil banks themselves to give away, but also hat there might be formed along the water line a sufficiently wide ledge 3B to serve as a gently shelving shore for the waves to break upon. For this reason, the width of the canal at the surface of the water was ncreased to 328 feet, as in *Fig* 3; and the inner crests of the spoil banks AA were made 394 feet apart, or 197 feet distance on each side from

the centre line of the canal This necessarily increased the quantity to be excavated, and means had to be devised for depositing on each bank 246 cubic yards of spoil per yard run, and a most successful solution of the difficulty was found in the adoption of extra long shoots. But it then became necessary to give the dredgers an unusual height and to make the shoots 230 feet long, and it was consequently impossible to retain the same arrangement of the parts as in the smaller dredgers. The new arrangement however presented the great advantage of doing away with cranes, ballast lighters, and especially wagons for removing the spoil, which, running over banks made of mud or wet clay broken up by the buckets, were constantly getting out of order Moreover with the aid of a few torches the dredger could be worked by night as well as by day.

The dredgers with the extra long shoots are shown in *Figs* 5 and 6, and are fitted with a single bucket-frame C like the others, the foot of which is ahead of the hull, the hulls are 108 feet long and 27 feet beam, and the upper tumbler D is 48 feet in height above the water. The shaft of the engine carries a drum working two centrifugal pumps, for supplying water to facilitate the discharge of the spoil through the shoots The length of the shoot E from the centre of the dredger is 230 feet, and its section is a half ellipse $2\frac{1}{2}$ feet deep and 5 feet wide; the width of the vertical well into which the buckets discharge the spoil being greater than that of the shoot, a tapering junction is made of as great a length as possible The shoot is stiffened lengthwise by two lattice girders which rest on the bottom of an iron lighter F placed at about one-third of their length from the dredger, the uprights G supporting the shoot are not fixed to the bottom, but jointed to a large horizontal spindle placed lengthwise in the lighter, and passing along its centre of displacement A horizontal hinge couples the shoot to the dredger, and allows of its inclination being altered, this joint is covered by a piece of leather protected by sheet iron, over which the spoil passes, the leather and iron being fixed to the dredger only. In order to allow of changing the inclination of the shoot the uprights G resting on the lighter are made telescopic. The shoot is lifted by two small hydraulic presses worked by hand, blocks of a suitable thickness are then put into the slides of the uprights G, and the whole is bolted together.

For the purpose of facilitating the transport of the shoots, the frame-

work supporting the shoot is cut in two horizontally above the slides just mentioned, so that when the shoot is detached from the dredger it can be turned on a sort of platform and brought into a position lengthwise with the lighter, the outer end being put upon a boat for that purpose As it is necessary that the dredger in traversing across the canal from side to side should carry its shoot and lighter with it, the lighter is connected to the dredger transversely by a pair of chains HH, *Fig.* 6, with horizontal struts at right angles to the two hulls to serve as distance pieces, and a second pair of chains JJ run from the stern and bow of the dredger to the bow and stern of the lighter, whereby they are securely stayed together longitudinally A pair of iron frames KK fixed to the dredger, and resting on the lighter and attached to it, make the two hulls like one piece in their vertical movements

Many of these dredgers with long shoots are now at work satisfactorily, and fully realise what was expected of them, and twenty more are being constructed. It was feared that the swinging or traversing movement of the dredgers across the canal from side to side might be attended with some difficulty on account of their mass, and from the wind acting with so great a leverage, but these fears are found to be without foundation, as the dredgers are shifted just as easily as those discharging into ballast lighters The swinging movement of the dredger is performed by means of chains L L, *Fig* 6, from the four corners of the dredger to anchors with very broad and strong flukes. These chains pass through hawse holes 3 to 5 feet below the water, leaving sufficient depth of water above them for the boats actually used on the canal to pass over the chains, the hawse holes are found to wear away very quickly.

Only one form of bucket is used, of elliptical section and very conical, as shown in *Figs* 7 and 8, and as this empties very easily, it has not been considered necessary to try any other forms It should be borne in mind that, beyond a certain size, the buckets empty very well even when they work in sticky clays, because the adhering surface of the spoil is simply proportional to the square of the dimensions, whereas the volume and consequently the weight of the spoil is proportional to the cube of the same dimensions Thus the weight increases more quickly than the adherence, and consequently the latter is always overcome beyond a certain limit of dimensions.

With these dredgers 48 feet high it will be easy, with the exception of

certain short portions where the ground is too high, to complete the cut across the Mediterranean lakes and the Suez plain, *Fig* 2, which form the two ends of the canal, and also to excavate the approaches of the Bitter Lakes, the whole amounting to more than half the entire length of the canal Before constructing the dredgers 48 feet high however, it was necessary to proceed cautiously in exceeding the dimensions of the first dredgers of only 26 to 30 feet height, and experience showed that it was necessary to devise some new method for getting rid of the spoil in the higher ground The formation level of the canal is throughout at the same height, and consequently the cubic quantity of spoil increases very rapidly as the ground rises, and as the crest of the spoil bank deposited on this high ground must be at least so far below the extremity of the shoot that the largest lumps which the buckets bring up may easily be got rid of, the height of the shoot, and consequently of the dredger, increases much more rapidly than the depth to be excavated. This necessitates increasing the strength of all the framework, the length of the bucket frame, and the weight of the chain of buckets, but the pins and links of the bucket chains had already reached very considerable dimensions and weights in the original dredgers, which made them inconvenient to repair. The first trial was made with dredgers only 10 feet higher than the original ones, and then excellent working encouraged the making of others still 10 feet higher, but it was evidently impossible to go much beyond the last height of 48 feet

In order therefore to excavate the short lengths of the canal where the ground is too high for even the long-shoot dredgers of 48 feet height, an attempt was made to work with cranes carried on the canal banks, having 33 feet radius of swing, which were to take up the boxes filled by the dredgers and brought alongside in floats. The arm of the crane not being long enough to discharge more than a small quantity on the spoil bank, the remainder was to be run off in trucks in the ordinary way. The first thing necessary was that the canal banks and slopes should be sufficiently solid to carry the cranes and rails and loaded wagons, when sloped at the inclination of 1 in 2, which was necessary for allowing the floats to come alongside. After some months' trial on the most favorable portions of the canal, it was found that the action of the water on the slopes, and their general want of solidity under the weight put upon them, rendered this plan defective. The object then was to find some arrangement of

mechanism which, whilst it should be capable of movement longitudinally, should be steady laterally, and should discharge at least one-half of the spoil direct on to the bank, without the use of wagons or any further handling

These considerations led to the construction of an Elevator, which is shown in *Figs.* 9 and 10, and consists principally of two lattice iron girders MM, placed at right angles to the canal and resting half way on the bank, these support a pair of rails NN inclined about 1 in $4\frac{1}{2}$, the lower end being about 10 feet above the water, and upper end about 46 feet. A truck P running on the bank parallel to the centre line of the canal, 6 feet above the water, supports the girders in the middle, and the lower half towards the water rests on a lighter Q, the centre of which is 26 feet from the lower end of the girders, the upper half towards the shore is completely overhanging The girders are tied together by vertical struts, and are strutted between their lower plates. The gussets at the middle are joined above the rails in an arch, and at their lower ends, widen out and rest on the truck P. The two girders are thus supported at two points 13 feet apart which gives them sufficient stability transversely, but allows of vertical oscillation, so that the inclination can be suited to the level of the water. They are attached to the lighter Q by a cast-iron block fitted with two trunnions placed horizontally and at right angles to each other; to this piece are secured four uprights, in the shape of an inverted pyramid, which are rivetted two and two to the girders, thus forming a universal joint.

On the inclined rails N of the girders runs a trolly R with external wheels, the pair of wheels at the lower end are fixed upon their axle, while the other pair are loose, and the axle of the latter carries two pairs of drums of different diameters cast in one piece On the smaller drum is coiled a chain, to which the boxes U filled by the dredger buckets are to be hooked; on the larger drum is coiled in the contrary direction an iron cable, which passing over a pulley O at the top end of the elevator, runs down to a winding drum I, fixed to the supports of the girders on the lighter Q. The drum I is worked by a two cylinder engine, the boiler is in the lighter, which contains also the water tanks and coal bunkers; and as the engine itself is fixed to the girders MM, the steam pipe passes through the universal joint uniting the girders to the lighter. The elevator is worked in the following manner Supposing the trolly R is at the lower end of the incline and consequently outside the lighter,

a float W is brought underneath, carrying boxes UU filled with spoil by the dredger, one of which is hooked on to the chain, and the engine set to work. The first effect is that the cable uncoils itself from the larger drum on the axle of the trolly, thereby winding up on the smaller drum the chain hooked to the box U, which is thus lifted until the stop touches the drum S, and as the chain cannot then be wound up any further, the cable drags the trolly up to the top of the incline, where the spoil is tipped by a self-acting movement. For tipping the spoil, a pair of rollers are placed at the back of the box U and on the lower side, which are caught between two pairs of guiding rails YY parallel to the incline of the elevator, and shortly before getting to the top of the incline these guides rise in a curvilinear line, as shown in *Fig.* 9, so as to tip the box into a nearly vertical position for emptying out the spoil. By reversing the engine, the trolly is allowed to run down to the bottom of the incline, and the box is lowered back again into the float.

The boxes U hold 4 cubic yards each, and their shape is similar to that of tip wagons, the bottom is lined with thin sheet iron, and they are made somewhat narrower at the back than in front. The flap door at the front end is hinged on the upper edge, and kept shut by a catch on each side, which is released by a self-acting chain at the moment of tipping the box. The floats W carry seven boxes each, they are made of two long rectangular chambers of sheet iron, 57 feet long, 8½ feet wide, and 4 feet high, these are kept 10 feet apart by eight openwork partitions between which the boxes are put, and when fully loaded they are almost entirely sunk in the water. Each dredger will ultimately have two elevators, one on each bank, and will get out a section of 300 to 450 yards length. If the final depth of the canal has to be excavated in three or four stages, the dredger will go up and down the length so many times, but the elevators will go only once.

In the Suez plain there was some difficulty about conveying the dredgers to the place where they were to commence work upon the line of the maritime canal, and it was impracticable to put them together on the spot. They are therefore put together and tried at Port Said, whence they are brought by water to Ismailia, and so passed into the freshwater canal by the two locks situated there; and they are then conveyed along the fresh water canal to a point about 5 miles from Suez. At this point, has been excavated a sort of basin opening into the freshwater canal, and

beyond is a second basin serving as a lock chamber; a communication is made between the two basins, and the dredgers with 82 feet shoots are floated into the second. They are then set to work and scoop out the bottom 6 feet deep below the sea level, and the communication between the two basins being stopped and the water allowed to escape from the second basin, the dredgers descend to their final level. They then cut their way to the line of the maritime canal and turn north and south, cutting a side trench right and left, along which the dredgers with 230 feet shoots can follow and complete the work.

In order not to be exposed to the rise and fall of the tide, the cut will not be made into the Red Sea until the works are sufficiently advanced for admitting the water into the smaller of the two Bitter Lakes, which will be temporarily shut off from the larger one by a small embankment constructed upon the ridge that forms the division between the two lakes, *Fig* 2. A weir will then be put up at the mouth of the cut at Suez, having its upper surface at about the level of mean water, and fitted with sluices, so as to be able to retain the water in the canal up to the required level The fall of the tide would otherwise impede the working of the dredgers.

The modes of working already described are those employed for cutting the canal wherever the surface of the soil is less than 6 feet above the sea level, that is, over a section about 56 miles in length, and including about 50 million cubic yards of excavation. Of this work the different implements have the following shares respectively allotted to them: dredgers delivering into sea-going ballast lighters, 13 million cubic yards, dredgers with elevators, 6 million cubic yards, dredgers with long shoots, 31 million cubic yards.

The higher ground along the line of the canal comprises the elevated table-lands of El Guisr and Serapeum and the high ground at Chalouf, *Fig*. 2. For the excavation at El Guisr, a cut was originally opened by hand labor to a level somewhat below that of the sea, and this cut is now being completed to the full width in the ordinary way, with wagons loaded by hand and drawn by small contractors' locomotives, in some places excavators are used for loading the wagons. This portion of the canal will then be completed by dredgers coming up from Port Said, which will deliver their spoil into lighters with flap doors at the bottom, and these will empty in Lake Timsah, *Figs*. 1 and 2.

The lighters with bottom doors are 108 feet long with 23 feet beam, carrying 160 cubic yards of spoil, and drawing 5 feet of water. They are fitted with twin screws and a pair of cylinders placed end to end, the engines work at high pressure without a condenser, with a tubular boiler at 120 lbs. pressure, using only fresh water. Whether loaded or light they make good a speed of 3 to $3\frac{1}{2}$ miles an hour, and although made specially for lake work they can put to sea Their construction is simple and economical, and it is found that high pressure engines are preferable to those of a medium pressure, as being simpler, lighter, and easier to keep in working order, and consequently more to be relied on for continuous work

For the Serapeum cutting, *Figs* 1 and 2, there is no means of bringing the dredgers and lighters in at the northern end direct from the Mediterranean, as at El Guisr, and they are therefore got upon the line of work by a similar plan to that already described in the case of the Suez plain, by cutting a channel from the freshwater canal to the line of the maritime canal As the level of the freshwater canal is 20 feet above the sea level, it is not possible in this case for the ballast lighters to empty into Lake Timsah until the cutting has been excavated down to 6 feet below the sea level, and for depositing the spoil, it was therefore decided to take advantage of three natural hollows which were found to extend transversely right and left of the line of the maritime canal, being formed by the undulations of the ground By embanking these hollows at suitable points, and then filling them with water from the freshwater canal, shallow lakes are formed, of sufficient capacity to receive from the ballast lighters all the spoil excavated by the dredgers down to a depth of 26 feet below the freshwater canal, or 6 feet below the sea level. When the bottom of the cutting has been lowered to this depth, the communication with the freshwater canal will be shut off, and the water allowed to run out into Lake Timsah; the dredgers will then begin again and work out the canal bed to its final level, the ballast lighters discharging in Lake Timsah.

For emptying the spoil in the shallow water of the temporary freshwater lakes, it became necessary to seek some new arrangement by which the ballast lighters could discharge in a very shallow depth, and the lighters constructed with flap doors at the sides are found fully to answer this purpose. These lighters are 106 feet long, the well AA, *Fig.* 12, is 65

feet long, and is divided into two portions by a longitudinal air chamber B, of a triangular section, the bottom of the boat, which is flat, forms the longest side of the triangle, and the vertex of the triangle is about level with the gun-wales The well AA is also divided across by five partitions into twelve compartments, the sides of the lighter are inclined slightly outward towards the top, and the flap doors of the compartments are hinged at the top, these doors are 4 feet high. The winches working the doors are inside the air chamber B, which is entered from both ends of the boat The engines and boilers, which are the same as those on the other lighters with flap doors at the bottom, are in a compartment at the stern. These lighters carry from 100 to 120 cubic yards, and draw 4 feet of water.

The high ground at Chalouf, *Fig.* 2, will be cut through dry, and the stuff removed with barrows and wagons, these latter are entirely of iron, and hold $2\frac{1}{2}$ cubic yards each. This portion, when excavated sufficiently low to admit the water from the Red Sea, will be completed with dredgers in the same way as the other portions, the spoil being discharged in the smaller of the two Bitter Lakes by ballast lighters with bottom doors. The sand on the previous portion of the canal was found to be completely impermeable to water when a certain depth was wetted, but the same is not the case here, as in the Suez plain the soil is clayey, mixed with some beds and pockets of sand. It has therefore been necessary to put up centrifugal pumps to keep the water under in the cutting, as the leakage is considerable from the freshwater canal, which is here at only a very short distance from the maritime canal. This water is run back into the smaller of the two Bitter Lakes.

To keep the numerous dredgers and engines in working order, there are large shops at Port Said, and ten small shops on the different sections. In reference to the repairs, it may be mentioned that, in the first dredgers used at Port Said, the pins of the bucket chain were made some of iron, others of soft steel; but when working in the sand a pin of 2 inches thickness was found to be completely worn away after 16,000 to 20,000 cubic yards had been got out, and three or four days' stoppage was required to put in a new pin. The wages alone for the dredgers however amount to about £4 per day, with another £4 to £6 for the bargemen of the ballast boats, making a loss of about £8 to £10 per day when they were stopped, and 4000 cubic yards would have been excava-

ted during the three days. Pins $2\frac{3}{4}$ inches diameter with triangular heads were then made of the hardest possible steel, the head is fixed in the double link, so that the single link takes all the wear, the eye being bushed with the hardest steel. After a certain time the pins are turned round one-third, and 48,000 cubic yards can now be excavated without turning the pin.

The upper tumblers of the dredgers, are made of cast-iron, the arrises being steel, and sometimes these had to be replaced twice a month, which was a work of three or four days each time These angle pieces, which had to be drilled and fastened on, have now been replaced therefore by a simple square steel bar at each of the four corners, passed through the flanges of the tumbler, and secured by a key. Each of the four wearing faces of the tumbler is also protected by a steel plate let in with a dovetail and secured by screws

The following observations have been made as to the manner in which the different sorts of spoil pass down the shoots of the dredgers. The fine sands, which are the only sands met with, pass easily down a shoot inclined 1 in 20 or 25, if mixed with a quantity of water equal to about half their own bulk. When the shoot has a less inclination than 1 in 25, the water separates from the sand, which is thus deposited all along the shoot in layers of continually increasing thickness; the addition of water does not seem to have any effect, and it is necessary to stir it up with a shovel. When the sand contains any shells, they are deposited in the shoot even with an inclination of 1 in 20, notwithstanding their lightness; and create round them deposits of sand, which continually increase, and have to be got rid of with shovels, or better still by increasing the inclination of the shoot. In this case again, an increased quantity of water is not so efficacious as increasing the inclination of the shoot. Different degrees of fineness and muddiness in the sand, and different sections more or less flattened of the shoots, require different inclinations of shoot.

The top of the spoil bank has the same width as the extent of side motion of the dredger. The inner slope is more or less steep according to the means used to support it; the outer slope, if the top of the bank is high and the spoil has but little height to fall from the end of the shoot, varies from 1 in 16 to 1 in 25. The more muddy the sand is, the gentler is the slope When the top of the bank is low, and consequently

the spoil falls from a greater height, the outer slope is gentler still The sand when got out occupies only 2 or 3 per cent more cubic space than in the solid.

Mud behaves very much like sand, if it is sufficiently soft to mix with water, and it will then pass down a shoot set with scarcely any perceptible inclination The very softest mud, such as that got out of the old channels previously cut through the clay ground, does not require the addition of any water in the shoot. With clay it is quite different, the addition of water washes away only a very small quantity of the material, and hardly breaks up the lumps at all. If each lump of clay were to slide perfectly straight down the shoot, all would work well, most commonly however, a lump winds about and soon stops, and the contents of the next bucket then drive it on 5 or 10 feet, and the whole increases the block Others come after and increase the stoppage, till the mass gets 12 or 16 inches in thickness, and reaches to the top end of the shoot, when the contents of the succeeding buckets seem to break it up, and the mass descends quietly and regularly in pieces of about 3 to 6 feet length. The shoots for clay are inclined from 1 in 12 to 1 in 16. With an inclination of 1 in 20 the lower end gets choked, which tilts that end of the shoot down and empties it, the work being thus carried on intermittently, with an inclination of 1 in 12 to 14 the work is more regular. When the clay is mixed with sand, the surface acts like a rasp, because the water washing away the clay makes the grains of sand more prominent and cutting, and thus seems to be rather detrimental. This is also the case when the buckets bring up hard clay and mud, the mud lubricates the clay and makes it run down more easily, whereas the water only washes the mud away.

In short, experience has shown that whilst a considerable supply of water must be added to sand, it is not so for mud or clay, to which only just enough water must be added for moistening the mass. Jets of water have not given good results, they merely wash down the points against which they are directed, and do not break up the lumps. The simplest and most convenient plan has been to put up a foot-way along the side of the shoot, and keep three or four men at work with scrapers to prevent its choking. In the long-shoot dredgers, with shoots of 230 feet length, an endless travelling chain is employed, as shown in *Fig* 5, driven by the engine and furnished with a series of scrapers to carry the clay down the

shoot Generally the greatest dificulty with all kinds of spoil is in passing the first 40 or 50 feet length of the shoot, when once the material has passed this with any given inclination, it continues moving on down the same inclination without further difficulty.

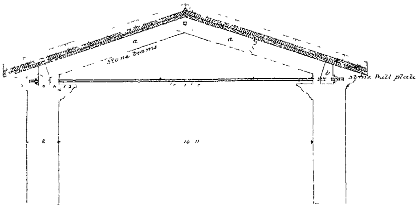
M Borel subsequently stated, that there were 40 Dredgers at work upon the Canal, which number would be ultimately increased to 60, each excavating from 30,000 to 40,000 cubic yards per month

One of the long-shoot dredgers had actually excavated 58,000 cubic yards between 15th April and 15th May, the whole of the spoil being deposited upon the banks in its final position, so as not to require any further shifting.

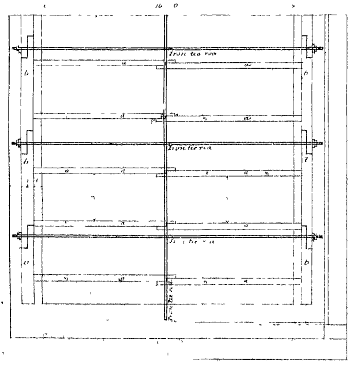
The jetties at Port Said were being constructed of sand mixed with lime brought from France ; this cement was made into cubical blocks of 20 tons each, which were carried out to sea in boats and sunk in the required spot. About 600 or 700 blocks were deposited per month.

STONE TRUSSES IN CENTRAL INDIA.

Section



Plan



No. CCXXI

STONE TRUSSES IN CENTRAL INDIA.

Note on Stone Trusses in use on the Northern Division, Agra and Bombay Road. BY TALBOT HAMILTON, ESQ., *Exec. Engineer*

IN this part of the country, where wood is both scarce and dear, while stone beams of all kinds are plentiful, a very useful truss was devised by, I believe, Mr Dodd (then Executive Engineer of this Division), in 1861, which can be used with great facility up to spans of 20 feet.

The rafters consist of stone beams 12 by 5 inches, placed 3 feet apart An iron rod runs through holes pierced in the end, and serves as a kind of ridge rod to keep them in position Stone wall plates, shaped as shown in the *Plate*, keep the feet of the rafters in their places, and are tied together at intervals by iron tie-rods The roof covering may consist either of a double layer of slabs breaking joint and terraced over, or of a single layer terraced and then covered with tiles, the latter makes a cooler roof than the first, and both are perfectly water-tight The ridges are tiled. The sketch will, it is believed, supply all needful information. The cost of this roof varies from Rs 30 to Rs 40 per 100 square feet according to the distance the beams and slabs have to be carried.

T. H.

No. CCXXII.

THE MONT CENIS RAILWAY

A short description of the Fell Railway, Mont Cenis Pass By LIEUTENANT-COLONEL DAVID BRIGGS, *Bengal Staff Corps*

THE summit of the Mont Cenis Pass was found by Aneroid observation to be 4,547 feet above St. Michel in Savoy, and 5,047 feet above Susa in Piedmont

It is between these towns that the Fell Railway has been laid The rise and fall added together make a total difference of level of 9,594 feet, and the railway has accomplished this in a distance of 48 miles,—its total length.

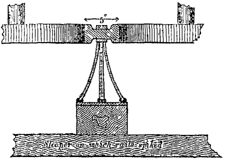
In consequence of the short period of the concession granted to Mr Fell, his company were unable to engage on the construction of a new road on which to lay the rails. He consequently adopted the old carriage road, laying the rails, as a rule, on the extreme outer edge of it, but occasionally crossing it level. He was thus subjected to the irregular gradients of the old road, and the very considerable difficulties of the numerous "zig-zags" A uniform gradient of 1 foot in 25 would have accomplished the task within the same number of miles, had he been able to select his own line. But, as it is, the maximum grade is 1 foot in 11 and the minimum radius of curve 40 metrés, or 43·745 yards. The express train accomplishes the distance in five hours

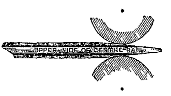
The irregularity of the gradient,—the sharpness and frequency of the curves,—the absence of any straight lines, give the whole affair a "rough and ready" appearance. An American Engineer of the Pacific Railway, with whom I afterwards travelled, was impressed with the "thoroughly American style of the whole thing." But it admirably answers its purpose, and sufficiently proves the possibility of safely running railway trains

through mountainous countries without incurring heavy works, or large expenditure.

Mr. Fell's system, as is well known, differs from that of the ordinary railway, in the addition to the engine of horizontal pairs of wheels which grasp a central rail. These wheels bite the central rail about 14 inches above the level of the ordinary side rails, and they are driven by the action of machinery unconnected with that of the ordinary vertical driving wheels. By the compression of these horizontal wheels, the driver can put a pressure equal to 56 tons upon the central rail; and I was told, could bring the train to a stand still within 100 yards.

The centre rail is only placed at those parts of the line where the grade is above 1 foot in 30, or where the radius of the curve approaches the minimum. The centre rail is a double T, as per sketch in margin, fixed by three iron curved legs at a height of 14 inches above level of side rails. As the engine arrives at a spot where the centre rail is fixed, the horizontal wheels take hold of it, and by the driver are made to bite with less or more power, as the occasion requires. At each end of the portions of centre rail, the ends are fined off thus—so that the wheels may enter fairly upon it. Each passenger carriage is also furnished with two pairs of horizontal wheels, but they have no apparatus to compress them on to the centre rail, and are simply guides to lessen the risk of the carriages running off the line at the sharp curves.



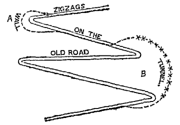


The width or gauge between the ordinary side rails is 42 inches from centre to centre. This narrow gauge is necessary in consequence of the sharpness of the curves. The rails are light and spiked on to cross sleepers without chairs being used. The sleepers seem to be generally of rough hard wood, cleaned on two sides.

The sharpness of the curves would, it was at first thought, necessitate

the use of short four-wheeled carriages, but by the application of "radial axles" on the middle pair of wheels, long carriages running on six wheels have been successfully used. This is a very ingenious invention. As the long carriage passes round a curve the middle pair of wheels leave the alignment of the front and back pair, and follow the curvature. The carriage retains its rigid position between the front and rear pair of wheels. The driver of the train told me it answered well, though at first grave doubts were entertained about it. The carriages are fitted in omnibus fashion, the seats being lengthways instead of across. They are coupled close, and platforms between each carriage enable the guards to pass from one to the other. Each carriage is fitted with a break, and they are continually being worked throughout the journey.

As stated before, Fell's railway generally follows the carriage road, taking the extreme outer edge of it, a strong rail separating it from the road. It does not occupy more than 8 feet of width. It crosses the carriage road level at many places, and does not seriously interfere with the traffic. It only necessarily diverges from the carriage road at two "zig-zags," of which there are many, especially on the Italian side of the pass.



At these places it leaves the road at some little distance from the angle of the "zig-zag," and sweeps round at maximum grade and curve. In some places this is effected by heavy retaining walls as at A, and at a few others by short tunnels turning two "zig-zags" into one, as at B. (The dotted line represents the railway.)

The maximum speed is 10 miles an hour.

The whole undertaking is characterized by boldness and expediency, and when carefully examining it, I could not but be struck with its fitness for the roads which communicate between the plains of India, and the Hill stations. These are frequently of too little width for the safe traffic of wagons drawn by animal power, but they are amply wide enough for such a line of Railway, as I have described.

D. B.

11th December, 1868.

No CCXXIII

ECLIPSE OBSERVATIONS OF THE G. T. SURVEY.

Extracts from the Reports on the Total Eclipse of the Sun of 18th August, 1868. [From the Annual Report of the Superintendent G. T Survey for 1867-68.]

Report by Lieutenant Herschel, R E

It is perhaps necessary in the first place to explain the circumstances under which I became connected with these observations as an employé of the Royal Society of London. Attention was drawn to this eclipse as important to science by Major Tennant, R E., early in 1867. I was at that time in England on sick leave, and in May of that year, a proposal was made to me, on the part of the Royal Society, to undertake certain observations of a definite character (the nature of which I shall have occasion to describe presently) should my return to India and other considerations make it possible. As you are aware, I accepted the proposal subject to your approval, and accordingly the Royal Society decided to purchase instruments suitable to the occasion, while I turned my attention to the branch of science involved—that of "spectral analysis"—and addressed you with a view to ascertaining how far I was justified in accepting the position.

It thus came about that on the expiration of my leave, I returned to India in charge of certain instruments entrusted to me by the Royal Society, and with a paper of instructions, indicating the character of the desired observations, in my pocket. I landed at Madras on the 8th December and the eclipse was to take place on the 18th August. The intervening time was in great measure devoted to my professional duties as a member of the Survey department—first in assisting at the measurement of the base-line

at Bangalore, and afterwards in the computations arising out of it, but the whole of my leisure was spent in practising with the instruments, and in preparations and arrangements. As these were necessary, rather than interesting, I need not enter into details about them, further than to show the precautions requisite to ensure, if not actual success, at least a reasonable probability of it

It is necessary, however, before proceeding further, that I should sketch the nature of the observations proposed That light may be separated into its constituents and those constituents *sorted* and arranged according to their colors, in passing through a wedge or triangular prism of glass, has long been known, also that solar light so distributed produced a "Spectrum" of a definite character was also known, and its peculiarities had been closely observed, but it was only within the last 8 or 9 years that a theory was propounded, which has since been very generally accepted, that these peculiarities viz .—Fraunhofer's lines—were due to a solar atmosphere, which, according to the theory, absorbs a portion of the light emitted by the body of the sun. This theory was based mainly on the observed identity of position in the spectrum, of these lines with those of light known to be emitted by certain definite elementary substances when intensely heated, the only difference being that the latter were *bright* lines while the former were dark. And the explanation of this difference was that they were dark by comparison only So that if the sun were supposed to be enveloped in vapours of the elementary substances—intensely heated indeed, and luminous perhaps, but *less so* than the central body—certain portions of the light from the latter would be absorbed, in favor of light of precisely the same kind, only less luminous, and therefore by comparison with the unobstructed light, dark.

The use of the prism in analyzing light is of very much larger application than any thing I have sketched here, and it would be quite out of place to attempt to explain the tests which it applies Suffice it to say that the appearance of the spectrum may or may not indicate the source of the light, as well as the chemical and physical constitution of that source.

The appearances presented during an eclipse, as seen through telescopes, had suggested all manner of theories as to the constitution and nature, both of the corona and red prominences At the last great eclipse—that of 1860—spectroscopes were unknown. It was not till two years later

that sufficient advance had been made in this direction to enable Mr Huggins, whose name is so well known in connection with this most interesting branch of physical discovery, and Padre Sacchi of Rome, to commence the spectroscopic examination of celestial objects. To their discoveries I need not refer further, except to point out how they naturally excited a lively interest, and a strong desire to apply the new implement to the solar appendages during a total eclipse, when the comparatively blinding light of the sun's body should be obscured.

To make more clear the special questions which a spectroscopical examination of the corona, &c., was expected to aid in solving, I should add that a "spectrum" has of necessity one of two characters It is either *continuous* or *discontinuous*, *i e*, the series of colors is either unbroken, or is only a series by courtesy, one or more representative colors only occupying their proper places, the rest being absent. These characters indicate whether the light emanates from a luminous solid or liquid, or or from a luminous gas or vapour, and in the latter case may, and some day no doubt will, indicate certainly from *what* gas or vapour

On the supposition that the "corona" was a solar atmosphere, the questions arose. Is that atmosphere, a self luminous vapour or mixture of vapours? and in that case, of what vapours does it consist? Or, is it a non-luminous vapour rendered visible by the reflection of the solar light from its material particles? Or, again, does it consist of strata showing both these characters? and others of a like kind.

Again, there was a still greater curiosity, if possible, to learn something about those strange appearances called, for want of any knowledge of their real nature—"protuberances," "prominences," "flames," and the like. Were they really flames? and if so, flames of what? On all these points the spectroscope, if it spoke at all, would certainly speak the truth, and science seemed fairly able to interpret the oracle by the help of late discoveries in terrestrial physics.

The event, which so far as I was concerned in it, I now proceed to relate, has in great measure answered these questions, thereby, as in all cases of scientific search, limiting speculation and pointing the way to fresh questions, to be answered, it is hoped, on some future occasion.

The instruments placed in my hands for these observations—as well as for another kind which I shall advert to presently—were

1st. A fine equatorially mounted telescope of 62 inches focal length

and 5 inches aperture, with clock-work driving machinery to ensure an automatic maintenance of direction upon a moving object and in connection with it, though an independent instrument.

2nd. A spectroscope containing a single flint glass prism for the separation or analysis of whatever light might be collected and thrown upon it by the above telescope.

The latter of these two I should observe, acts the part of a large, and in some respects inconvenient, *eye-piece* to the former, with this difference as compared with an ordinary eye-piece, that whereas the latter presents to the eye a magnified image of the objects towards which the telescope is directed, the former offers no such advantage, but only receives and *sorts* the light and presents the resulting arrangement for inspection, quite devoid of any *form* corresponding to that of the real object. It will therefore be understood that I had to make up my mind to see nothing of the eclipse *as a spectacle*, with the fine telescope at my command. Nor did I · were it otherwise, I should confine myself in this report to a description of a more generally interesting character than I am now enabled to offer.

Having now given an outline of the proposed objects, and sufficiently indicated the nature of the instruments, I need not dwell on the preliminary arrangements—among which, however, I should mention the construction of a portable wooden observatory (which I contemplated making use of afterwards for survey purposes) and the choice of a station of observation. With regard to the last, I may take this opportunity to offer my grateful acknowledgment of your energetic assistance in procuring through the local Governments the necessary information as to climate and weather at numerous stations along the line of eclipse, and of your warm support, and concurrence, in all my endeavors to obtain for the Royal Society the best chances of success; more especially in procuring the sanction of Government for the necessary expenditure, and in giving me the assistance of Lieutenant W. Maxwell Campbell, R.E.

The station selected, with your approval, was Jamkandi—a small town notorious on the Bombay side for the small rainfall which characterizes the district in which it is situated. It is the residence of an independent native chief, well known in those parts for the enlightened taste which he displays in surrounding himself with the products of European skill and refinement, as well as for other reasons. I was, perhaps unduly, biassed in

this choice by the spontaneous offers of assistance made through his secretary, when the question of a suitable position was first mooted. I wish I could add that I had reason to congratulate myself on my choice In point of fact, it was by no means an easy thing to decide. There seemed a strong probability of cloudy weather, wherever we went, at that season, and access was not equally practicable to all places. The main road through Dharwar and Belgaum might reasonably be expected to be passable even in August, and Jamkandi was distant from it only 80 miles. Nevertheless, I was unwilling to risk sending my camp such a distance except in charge of an assistant I had received your permission to avail myself, to the full extent of my requirements, of the services of Lieutenant Campbell's assistants at Bangalore I proposed to enlist one of these gentlemen as a recorder and observatory assistant, and a second was required to take a series of independent observations of the intensity of the chemical action of sun-light during the progress of the eclipse I believe Lieutenant Campbell was a little doubtful whether the nature of the observations with which he was entrusted would be such as to require an assistant, but other considerations—arising out of his professional work, and requiring the detachment of an assistant in that direction—which will no doubt find a place in his regular report, induced me to consent to this further increase to the strength of the party.

Mr G Anding accordingly went as Lieutenant Campbell's personal assistant, and as the senior, in charge of the party To Mr. A. Christie I entrusted the photo-chemical apparatus, and instructed him in the use of it, while Mr J. Bond accompanied the party to act eventually as my assistant

The party left Bangalore on the 7th July and reached Jamkandi on the 9th August, having made a very creditable march of 392 miles over very bad roads, in 34 days, including halts

Lieutenant Campbell and myself followed later, arriving at Jamkandi on the 14th On the evening of the same day, the observatory was up and the instrument in position, but unadjusted

Before proceeding further, I will endeavor to describe the nature and object of the special observations which Lieutenant Campbell was about to secure. I have said that some of the questions which it was desirable to have answered, if possible, had reference to some remaining uncertainty as to whether the corona was or was not a solar atmosphere, or whether it

was not possibly of the nature of a terrestrial atmospheric halo This question appeared to be susceptible of solution by the help of the "polariscope"—an instrument for indicating the *plane of polarization* of light. Light being always more or less polarized by reflection, it was surmised that if the corona was *reflected* solar light, it should show some traces of this peculiarity when viewed with the polariscope, which instrument would at the same time indicate the plane of polarization and therefore the probable position of the reflecting surface, with regard to the source of light. It is hardly necessary to add that the polariscope is merely an adaptation to a telescope, of one or other of certain peculiar combinations of crystalline plates This instrument does not, as in the case of the spectroscope, materially affect the form or appearance of the object. In one case it presents two distinct fields of view, identical in every respect except that they are differently tinted when polarized light is present in the other, one view only is presented crossed by more or less faintly shaded and colored parallel bands, the direction and arrangement of which give the required information as to polarity So much of explanation seems necessary in connection with Lieutenant Campbell's report, copy of which I enclose.

I should also state that the Royal Society furnished me with 4 small instruments, called "hand-spectroscopes" for distribution according to circumstances. I was at some pains to give these instruments a fair chance, but, up to the present time, I have received no reports from which anything material can be gathered.

Two other instruments which I brought out myself—of a like nature—and which I lent to Mr. C S Chambers, Government Astronomer at Bombay, were rendered useless in his hands by cloudy weather. On the whole, these instruments have fared so badly that there seems no occasion to describe them here.

I may now return to the principal subject of this report, to which the greater part of the foregoing remarks must be considered as necessary an introduction, as the actual preliminaries were to the event. The interval from the 14th to the 18th August was occupied, as may be supposed, in anxious preparation and uncertainty. The weather was far from promising, being persistently cloudy, but we entertained hopes each day that it would be the last of an unusually protracted interval of such weather in that country. The uncertainty as to the phenomena to be witnessed, com-

bined with the uncertainty as to the space of time which the clouds might allow for observing them, rendered it almost impossible to lay down a definite course of action, and greatly heightened the nervous apprehension otherwise so natural to the occasion. To this cause I must attribute the almost complete abstraction whose result is so evident both in my own personal recollections of that morning, and in the absence of any observations of a generally interesting character which one might fairly be supposed to have made. I was closely imprisoned from 10 minutes before to nearly the same time after the total phase, and was sensible to nothing external but the hum of voices around me.

About 10 minutes before totality commenced, I took up my position at the telescope and occupied the interval in final measures of the solar lines—to which any subsequent measurements might be referred. As I was thus engaged, the spectrum of what remained of the sun grew rapidly narrower, and I was watching eagerly—and it may be guessed how intently! for the final disappearance which was to reveal, in place of the solar spectrum, that of the corona—when the latter faded prematurely through the intervention of a cloud, and the precious moment was lost.

I went to the finder, removed the dark glass, and waited, how long I cannot say, perhaps half a minute. Soon the cloud hurried over, following the moon's direction, and therefore revealing, first, the upper limb with its scintillating corona, and then the lower. Instantly I marked a prominence near the needle point, an object so conspicuous that I felt there was no need to take any precautions to secure identification. It was a long finger-like projection from the lower left hand portion of the circumference. A rapid turn of the declination screw covered it with the needle point and in another instant I was at the spectroscope. A single glance and the problem was solved. THREE VIVID LINES, RED, ORANGE, BLUE, NO OTHERS, AND NO TRACE OF A CONTINUOUS SPECTRUM.

From that time until the end of the 5 minutes, I was endeavouring to seize the fitful glimpses of these lines for purpose of measurement. I succeeded with the orange and blue, but there was not sufficient time for the 3rd. The field became suddenly re-illuminated and the total eclipse was over. Nothing more could be done except to check the measurements against those of the solar spectrum.

Of the result of this comparison I will say as little as possible, for obvious reasons. My impression is that the flame I was looking at consisted prin-

cipally of sodium, and *possibly* hydrogen, in an intensely heated condition; but it would plainly be premature to indulge in speculations, when a little patience will supply other and independent data.

The absence of any spectrum of the corona is simply negative evidence, and nothing more can be based on it than the presumption that it was faint and probably "continuous," which would imply reflection of solar light rather than intrinsic luminosity On this point also, reserve is better than hasty speculation, although the conclusion to be derived from Lieutenant Campbell's observations of polarity—that the corona is not self-luminous but only a reflecting agent—is irresistible

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Lieutenant Campbell's Report.

I was deputed to accompany Lieutenant Herschel, on his expedition to observe the phenomena of the total eclipse, and to use the instruments supplied by the Royal Society, for the observation of Polarized light in the corona and red flames

The instruments in question were as follows:—

A telescope of 3 inch aperture, mounted on a rough double axis, admitting of motion in azimuth and altitude by hand only, unaided by any appliances for clamping and slow motion. The telescope was provided with three eye pieces of magnifying powers of 27, 41, and 98, and with it were furnished two Analyzers, for polarized light—viz., a double image prism and a "Savart's polariscope."

The first gives two images of the object viewed, which, when polarized light is present, become strongly colored with complementary tints, by whose changes, according to the position in azimuth of the analyzer, the plane of polarization may be found

The second shows the presence of polarized light by the formation, across the image of the object viewed, of colored bands, which alter in arrangement and intensity, according to the position of the polariscope with reference to the plane of polarization, and hence afford a means of arriving at a knowledge of the latter

With the former, slight polarization would probably be more readily recognised at a glance, while with the latter, the plane of polarization could be more easily and accurately determined.

To carry these analyzers, I had a pair of jointed arms constructed, so attached by a collar and screw to the eye tube of the telescope, as to admit of the eye-piece being changed

Each arm carried one of the analyzers in a cell, in which a rotatory motion could be given for analyzing purposes Either analyzer could in this way be brought instantly into position before the eye-piece of the telescope, or both could be turned aside and the telescope used by itself, at pleasure

Immediately behind this apparatus, a circular piece of card-board of about 12 inches diameter, and neatly graduated, was firmly attached to the eye tube, and to each analyzer was affixed a long pointer, by which its azimuth could be referred to the graduations on the card circle, should measures of position, or change of azimuth appear desirable I was also furnished with a hand spectroscope for direct vision

The point chosen for my station was on the northern slope of a low range of hills, about $1\frac{1}{2}$ miles W by S of Jamkandi.

The flatness of the hills on top offered no point, from which an uninterrupted view could be obtained in all directions, and from my station I only obtained a view of the northern half of the distant horizon, over the plains extending in that direction for many miles, above the general level of which I was raised about 200 feet.

Early on the morning of the 18th, I proceeded to the spot, having previously sent up the instruments, and a tent for shelter in case of necessity.

At sun-rise the sky was beautifully clear, except in the northern horizon, where there were low clouds lying over the river Kistna. There was a gentle breeze from W. by S. W. A little later, light flocculent clouds began to rise, and form in an arch overhead from west to east, continuing to increase, as the morning wore on, then a light scud set in and turned gradually into broken masses of thick dark clouds

Before the commencement of the eclipse, I took observations for time with a small theodolite, from which I computed the error of my chronometer (a mean time chronometer by McCabe) to be *1h. 14m. 55 2s. fast* on local apparent time, and by that quantity I have accordingly corrected all observed chronometer times, in the statements of time which follow

I observed the first contact, which took place at *7h 45m. 13s.* (local apparent time) about 15° from the vertex, after which I watched the pro-

gress of the eclipse, and noted the time of occultation of three spots which were visible on the sun

During the progress of the eclipse, I observed no unevenness in the moon's limb, nor any want of sharpness in the cusps—using magnifying power 27

The following notes were taken on the spot At first contact, Sun very slightly obscured by flying clouds. At *8h 0m.*, clouds thick and gathering, rising from S W. and W

Wind higher and gusty.

h	*m.*	
8	10	Clouds overhead, increasing and thickening, and rising steadily from west.
8	20	Sky nearly entirely overcast, clouds thickest in neighbourhood of sun
8	25	A clear break.
8	30	I thought I could discern very faintly the dark limb of the moon, beyond that of the sun, and at this time, making allowance for the general cloudiness, I did not perceive any decrease of light on the landscape.
8	40	But 10 minutes later the darkening was decided.
8	45	Thick clouds well broken up, still gathered most closely in the region of the sun Light becoming lurid, and increase of darkness very apparent
8	52	Cusps perfect (magnifying power 27).

Closely before totality, a bright line of light appeared to shoot out at a tangent to the moon's limb at its vertex, as if running across the bright crescent of the sun (though of course not visible against the superior light) and extended beyond each cusp to a distance of nearly or quite 15 minutes. The corona became visible immediately after, between the dark limb of the moon and the bright line. The corona did not appear so bright as the line, the brilliance and whiteness of the light of which was most striking. This was seen through a lightly smoked glass. At this period, probably not more than 3 to 5 seconds before totality ensued, a thick cloud shut out everything, and the rest of the phenomenon was only seen fitfully through openings in the clouds—for an aggregate period, which I estimate at somewhat less than half that of totality.

This alternate appearance and disappearance troubled me greatly, and

gave rise to nervousness and excitement, for, owing to the imperfect mounting of my telescope, I was apt to lose my place whenever the light was cut off by clouds, and waste the precious moments of clearness in finding it again On the first opportunity after the commencement of totality, I turned on the double image prism, with the eye-piece of 27 magnifying power, as recommended in the "instructions," which gave a field of about 45 feet diameter. A most decided difference of color was at once apparent between the two images of the corona, but I could not make certain of any such difference in the case of a remarkable horn-like protuberance, of a bright red color, situate about 210° from the vertex reckoned (as I have done in all cases) with reference to the actual, not the inverted image, and with direct motion. I then removed the double image prism and applied the Savart's polariscope, which gave bands at right angles to a tangent to the limb, distinct but not bright, and with little if any appearance of color. On turning the polariscope in its cell, the bands, instead of appearing to revolve on their own centre, passing through various phases of brightness, and arrangement, &c , travelled bodily along the limb, always at right angles thereto and without much change in intensity, or any at all in arrangement

The point at which they seemed strongest, was about 140° from vertex, and I recorded them as black centred.

Believing that with a higher power, and smaller field, I should find it easier to fix my attention on one point of the corona, and observe the phases of the bands, at that point, I changed eye-pieces, applying that of 41 power

With this eye-piece, the first clear instant showed the bands, much brighter than before, colored, and as tangents to the limb, at a point about 200° from the vertex , but before I could determine anything further, a cloud shut out the view, and a few seconds later, a sudden rush of light told that the totality was over, though it was difficult to believe that 5 minutes had flown by since its commencement

I experienced a strong feeling of disappointment, and want of success, the only points on which I can speak with certainty being as follows .— 1st, When using the double image prism, the strong difference in color of the two images of the corona, and the absence of such difference in the case of the most prominent red flame , 2nd, With the "Savart's polariscope"—the bands from the corona were decided. With a low power,

they were wanting in intensity and color, (excepting alternate black and white,) making it difficult to specify the nature of the centre, and their position was at right angles to the limb, extending over a space of about 30° of the circumference. When the polariscope was turned, the bands travelled bodily round the limb, without other change in position or arrangement, as if indeed they were revolving round the centre of the sun as an axis With a higher power when a smaller portion of the corona was embraced, the bands were brighter, colored, and seen in a different position, viz, as tangents to the limb

The appearance observed with the low power seems exactly what might be expected, supposing the bands to be brightest at every point, when at right angles to the limb; in which case, the bands growing into brightness at each succeeding point of the limb, would distract attention from those fading away at the points passed over, as the analyzer revolved

After totality was over, the clouds cleared somewhat, and I watched the eclipse till its conclusion, noting the times of emersion of the spots, last contact, &c.

A light shower fell at 9 30

During totality, several stars and planets were seen by those who were with me, and a fowl, which I had placed near me out of curiosity, was observed to compose itself to sleep. It was at no time so dark as I had expected, after the commencement of the total phase, I read the chronometer, and wrote notes in pencil without difficulty, and the light of a bull's eye lantern, when thrown on my paper, appeared somewhat dull

The brilliance of the light of the corona, when it burst out through the openings in the clouds astonished me. Also the very gradual decrease of light before totality, and the wonderful flood which followed the instant of the sun's limb's re-appearance (though behind a cloud) was very striking.

I was too much occupied in watching the position of the sun, so as not to lose an instant of the precious intervals of clearness, to see much of the general effect. I had no opportunity of using the hand spectroscope. There was no one in my neighbourhood (except those of my own party, who had been warned to keep silence,) but when totality commenced a wailing shout was heard in the distance, apparently rising all round us, which was succeeded by silence after a few seconds. The distant features of the landscape disappeared, and I noticed one light, apparently a village fire, some miles distant.

No. CCXXIV.

THE HIGH COURT—ALLAHABAD.

Summary of Specification and Report

THE soil being sound and firm, with but little sandy admixture, the foundations were carried to a depth of 4 feet, a layer of concrete of broken brick and oopla lime, 4 feet wide and 9 inches thick, was first laid, upon this rough coursed rubble stone to ground level.

Above ground level the external walls and plinth are of rock-faced coursed rubble, sometimes known as pitched faced rubble. The courses are generally about 5½ inches thick and the projection of the rock faces about 2 inches The stone for this work, except a small quantity, was obtained from the Government quarries at Purtahpoor* on the Jumna, and Sooraj-poor on the Jubbulpoor line, East Indian Railway. The stone is a finely grained light red sand stone, which works well, and can be obtained in any size and quantity The internal walls are of brick as well as the arching. The lower floor is composed of dressed flags averaging 2 feet square, set in mortar over 6 inches of ballast; the upper floor is carried on iron girders about 6½ feet apart, across which, sál rafters are carried, to take 1¼-inch deodar boarding the upper roof is also carried on girders, but with a single brick arch turned on its upper flange, and running the whole unbroken length of the girder

It was, however, subsequently found that the echo from these unbroken arches was so great, as to render it most difficult to hear a person speaking across the room, and the shutting of a door hastily caused a reverberation this was obviated by making light sál wood frames, across which good

* See No LVII, of these Papers.

doosootee was stretched and white-washed, the whole was made to rest on the lower flange of the girder, the under surface showing a series of heavy square panels which added much to the coolness and appearance of the rooms, and entirely stopped the echo.

The upper surface of the roof is pucka; that is to say, of broken brick concrete finely smoothed off and gradually sloping to the under walling of the verandah, down which cast-iron pipes are let to carry off the rain water.

The stairs are perhaps the part that most strikes the stranger, being what is termed geometric, the stones are bedded though the entire thickness of the wall, and project $5\frac{3}{4}$ feet, each step just resting about 2 inches on the one below; the principle being that of an inclined plane with its two lower ends supported, the pressure being therefore successively transmitted down to the base, the outer edge of which carries a handsome cast-iron, teak mounted, railing.

Ventilation has been preserved by a series of air holes left in the walls, connected with a main channel running along under the lower floor gallery, and passing outside to be connected with a steam blowing engine; the foul and heated air being carried off by large sky-lights placed over the main rooms, provided with tilting sashes; and by openings at cornice level, passing out to the verandah, protected with wire netting.

The doors leading on to the verandah are all double, viz, one glass and outside it a venetian, and in the lower story are surmounted with a semicircular glazed head, the interior doors are all panelled. All the joinery is of best teak wood, varnished and brass mounted.

The approaches from the front are kunkured to a breadth of 60 feet, and add much to the appearance of the building, young mango and other trees being planted among the grass plots

At the south-east corner and about 400 feet from the High Court, are being erected a set of out-houses similar in appearance to the main building for the convenience of the judges and officials, as it provides stabling and carriage room, and also a large central arcade for suitors and others waiting, besides servants' houses. Another is being built for the use of the High Court Bailiff.

It is proposed to fill in the upper portion of the inter-columnar spaces with either iron screens, stone louvering or canvas screens. A portion of louvering has been put up and colored to imitate stone, and instead of

detracting, seems to give an improved appearance. Another improvement is the opening out of the verandah parapet, which is supposed to choke the free current of air Some half dozen different designs have been tried, and it seems probable that the upper moulding will be left. As it is supported on two or three cut stone uprights, this will add to the lightness and elegance of the design.

As the subject of the blowing engine has not yet been gone into, punkahs have been supplied to all the main rooms.

This building is similar to three more—one for the Secretariat, which has just been occupied—one for the Revenue Department, which will be finished by next November—and one for the Audit Branch by the following March—the only difference being that the disposition of the rooms in each is slightly altered, according to their requirements

Water for the four buildings will be supplied by two wells, one of which has been sunk 165 feet, and finished, the other is in progress.

W C HENNESSEY, C E,
Exec. Engineer

No CCXXV.

NOTES ON THE SLIDE RULE.

(2nd Paper.)

By Captain W. H Mackesy, *Executive Engineer.*

In a previous article* on the subject of the Slide Rule, the writer showed that the general utility of the instrument might be increased by certain improved arrangements of the lines He has since had the improvement carried out in some Rules made to his order by Messrs Elliott, 449 Strand The rules are figured in the accompanying drawings, and are described below.

The Three-slide Rule is a triangular prism, with a slide on each face. No. 1 Face—has the usual lines A and D on the stock; on face of the slide, the lines B, C; and on the back, the line D—there is a spare slide for this face, with a line of cubes on one side, and of fifth powers on the other side No. 2 face has a line of sines on the upper part of the stock and of tangents on the lower part; one face of the slide has a line of sines, and the other face a line of tangents to 45 degrees No 3 face has a line of sines on the upper part of the stock and a line of sines to double radius, or of sines squared, on the lower part, and the slide has a line of tangents to double radius on one face, and a line of tangents to single radius from about 6 degrees to 84 degrees on the other face.

The Two-slide Rule is rectangular, and has, as its name implies, only two

* *See* No. CLXIII. of these Papers.

slides, the face of the stock with its slide is exactly similar to No 1 face of the three-slide rule, and the back of the stock with its slide is exactly similar to No. 2 face of the three-slide rule. There is also a spare slide with a line of cubes on one face and a line of tangents from about 6 to 84 degrees on the other side

In both Rules, any one slide, whether erect or inverted, can be worked with either face of the stock, although only some of the resulting combinations are of practical use The following table gives all possible proportions on the three-slide rule, and those which can be worked on the two-slide rule are distinguished by a remark to that effect.

A or A_1 signifies any number or angle read on the upper part of the stock
D or D_1 " " " lower "
B or B_1 " " " slide

AB or A_1 B_1 signify any pair of numbers read together on the upper part of the stock and a slide

DB or D_1 B_1 signify any pair of numbers read together on the lower part of the stock and a slide.*

It is to be observed, as a peculiarity of the rules now described, that the lines on all the slides read both above and below, this arrangement has the effect of more than doubling the power of the instrument. If any slide be inverted—thus

A	A	A_1
D / B (inverted)	B	B_1
D	D	D_1

the proportions are

$$A : A_1 :: B_1 : B,\ D : D_1 :: B_1 : B, \text{ or } D : A_1 :: B_1 : B$$

the proper indices, &c, for the various slides as given in the table being supplied.

TABLE OF PROPORTIONS ON THREE-SLIDE RULE.

Face of stock	Slide	No.		Proportions.	Remarks.
No. I	No I	1		$B \quad B_1 \ . \ A \ . \ A_1$	1 and 2 can be worked on all patterns of slide rules 3 can be worked on all patterns excepting carpenter's.
A and D	line BC	2	a	$B \quad B_1 \ . \ D^2 \ . \ D_1^2$	
			b	$\sqrt{B} \quad \sqrt{B_1} \quad D \ . \ D_1$	
		3	a	$B \quad B_1 \ . \ A : D_1^2$	
			b	$\sqrt{B} \cdot \sqrt{B_1} \quad \sqrt{A} \quad D_1$	

Face of stock	Slide	No		Proportions				Remarks
				To be worked on carpenter's slide rule only in which D line reads from 4 to 40 instead of from 1 to 10, as in the common pattern				This arrangement has no special advantage, and is inconvenient to use as it requires special gauge point
		3	*a*	B	B_1	16 A	D_1^2	
			b	B	B_1	A	$\frac{1}{4} D_1^2$	
			c	$\sqrt{B}$	$\sqrt{B_1}$	$4\sqrt{A}$	D_1	
			d	$\sqrt{B}$	$\sqrt{B_1}$	$\sqrt{A}$	$\frac{1}{4} D_1$	
	No 1 line D	1	*a*	B^2	B_1^2	A	A_1	
			b	B	B_1	A	A_1	
		2		B	B_1	D	D_1	
		3	*a*	B	B_1	$\frac{D}{2}$	$\sqrt{A_1}$	
			b	B^2	B_1^2	D^2	A_1	

Spare slide cubes	1	*a*	$B^{\frac{2}{3}}$	$B_1^{\frac{2}{3}}$	A	A_1	
		b	B	B_1	$A^{\frac{3}{2}}$	$A_1^{\frac{3}{2}}$	
		c	$\sqrt[3]{B}$	$\sqrt[3]{B_1}$	$\sqrt{A}$	$\sqrt{A_1}$	
		d	B^2	B_1^2	A^3	A_1^3	
	2	*a*	$\sqrt[3]{B}$	$\sqrt[3]{B_1}$	D	D_1	
		b	B	B_1	D^3	D_1^3	
	3	*a*	B	B_1	$A^{\frac{3}{2}}$	D_1^3	
		b	B^3	$B^2{}_1$	A^3	D_1^6	
		c	$\sqrt[3]{B}$	$\sqrt[3]{B_1}$	$\sqrt{A}$	D_1	
		d	$B^{\frac{2}{3}}$	$B^{\frac{2}{3}}{}_1$	A	D_1^2	
Fifth powers.			Exactly as for line of cubes, substituting the indices 5 for 3 and 10 for 6 wherever they occur				

Face of stock	Slide	No		Proportions				Remarks
No I	No 2 (Can be worked on two-slide rule)	1		A	A_1	sin B	sin B_1	Can also be worked on Bayley's erect or inverted
Line A & D	Sine	2	a	D^2	D_1^2	sin B	sin B_1	Ditto inverted on face of stock
			b	D	D_1	$\sqrt{\sin}$ B	$\sqrt{\sin}$ B_1	Ditto.
		3	a	D	$\sqrt{A_1}$	$\sqrt{\sin}$ B	$\sqrt{\sin}$ B_1	
			b	D^2	A_1	sin B	sin B_1	
	Tangt		5	Exactly similar to *sine*, substituting tangent B for sine B in each case				
	No 3 Tang (6° to 84°.) (Can be worked on two slide rule)		5	Exactly as tangt on slide 2				
	Tan²	1	a	A	A_1	tan² B	$\tan_2$ B_1	
	6° to 45°		b	$\sqrt{A}$	$\sqrt{A_1}$	tan B	tan B_1	
		2		D	D_1	tan B	tan B_1	
		3	a	$\sqrt{A}$	$\sqrt{D_1}$	tan B	tan B_1	
			b	A	D_1^2	tan² B	tan² B_1	
No 2	No 1	1		B	B_1	sin A	sin A_1	Bayley erect or inverted
Lines	B and C	2		B	B_1	tan D	tan D_1	Ditto
Sine and Tang		3		B	B_1	sin A	tan D_1	Ditto.
	D (Can be worked on two-slide rule)	1	a	B^2	B_1^2	sin A	sin A_1	
			b	B	B_1	$\sqrt{\sin}$ A	$\sqrt{\sin}$ A	
		2	a	B^2	B_1^2	tan D	tan D_1	
			b	B	B_1	$\sqrt{\tan}$ D	$\sqrt{\tan}$ D_1	
		3	a	B^2	B_1^2	sin A	tan D_1	
			b	B	B_1	$\sqrt{\sin}$ A	$\sqrt{\tan}$ D_1	

Face of stock	Slide	No		Proportions				Remarks
No 2	Spare	1	a	$\sin^3 A$	$\sin^3 A_1$ ..	B^2	B_1^2	
Lines	Slide		b	$\sin^{\frac{3}{2}} A$	$\sin^{\frac{3}{2}} A_1$	B	B_1	
Sine and Tang	Cubes (Can be worked on two-slide rule)		c	$\sqrt{\sin A}$	$\sqrt{\sin A_1}$	$\sqrt[3]{B}$	$\sqrt[3]{B_1}$	
			d	$\sin A$.	$\sin A_1$	$B^{\frac{2}{3}}$	$B_1^{\frac{2}{3}}$	
		2		Exactly similar to 1, tan D being substituted for sin A				
		3	a	$\sin^3 A$	$\tan^3 D_1$	B^2	B_1^2	
			b	$\sin^{\frac{3}{2}} A$	$\tan^{\frac{3}{2}} D_1$	B	B_1	
			c	$\sqrt{\sin A}$	$\sqrt{\tan D_1}$	$\sqrt[3]{B}$	$\sqrt[3]{B_1}$	
			d	$\sin A$	$\tan D_1$	$B^{\frac{2}{3}}$	$B_1^{\frac{2}{3}}$	
	Fifth Powers	9		Exactly as for line of cubes, substituting the index 5 for 3				

No 2 Sine	Can be worked on two-slide rule	1	$\sin A$	$\sin A_1$	$\sin B$	$\sin B_1$	
		2	$\tan D$	$\tan D_1$	$\sin B$.	$\sin B_1$	
		3	$\sin A$	$\tan D_1$	$\sin B$	$\sin B_1$	
Tangent		1	$\sin A$	$\sin A_1$	$\tan B$	$\tan B_1$	
		2	$\tan D$	$\tan D_1$.	$\tan B$	$\tan B_1$	
		3	$\sin A$	$\tan D_1$	$\tan B$	$\tan B_1$	

No 3 Tangt 6° to 84°	Can be worked on two-slide rule	3	Exactly as with line of tangents on No. 2 slide	
Tan² 6° to 45°				

Face of stock	Slide	No		Proportions				Remarks
No 2 Sine and Tangt	No 3 Tan² 0° to 45°	1	a	$\tan^2 B$	$\tan^2 B_1$	$\sin A$	$\sin A_1$	
			b	$\tan B$	$\tan B_1$	$\sqrt{\sin A}$	$\sqrt{\sin A_1}$	
		2	a	$\tan^2 B$	$\tan^2 B_1$	$\tan D$	$\tan D_1$	
			b	$\tan B$	$\tan B_1$	$\sqrt{\tan D}$	$\sqrt{\tan D_1}$	
		3	a	$\tan^2 B$	$\tan^2 B_1$	$\sin A$	$\tan D_1$	
			b	$\tan B$	$\tan B_1$	$\sqrt{\sin A}$	$\sqrt{\tan D}$	
No 3 Sine and Sin² None of the combinations on this face can be worked with the two slide rule.	No 1 B and C	1		B	B_1	$\sin A$	$\sin A_1$	
		2	a	B	B_1	$\sin^2 D$	$\sin^2 D_1$	
			b	$\sqrt{B}$	$\sqrt{B_1}$	$\sin D$	$\sin D_1$	
		3	a	B	B_1	$\sin A$	$\sin^2 D_1$	
			b	$\sqrt{B}$	$\sqrt{B_1}$	$\sqrt{\sin A}$	$\sin D_1$	
	D	1	a	B^2	B_1^2	$\sin A$	$\sin A_1$	
			b	B	B_1	$\sqrt{\sin A}$	$\sqrt{\sin A}$	
		2		B	B_1	$\sin D$	$\sin D_1$	
		3	a	B^2	B_1^2	$\sin^2 D$	$\sin A$	
			b	B	B_1	$\sin D$	$\sqrt{\sin A}$	
	Spare Slide Cubes	1	a	$B^{\frac{2}{3}}$	$B_1^{\frac{2}{3}}$	$\sin A$	$\sin A_1$	
			b	B	B_1	$\sin^{\frac{3}{2}} A$	$\sin^{\frac{3}{2}} A_1$	
			c	$\sqrt[3]{B}$	$\sqrt[3]{B_1}$	$\sqrt{\sin A}$	$\sqrt{\sin A_1}$	
			d	B^2	B_1^2	$\sin^3 A$	$\sin^3 A_1$	
		2	a	B	B_1	$\sin^3 D$	$\sin^3 D_1$	
			b	$\sqrt[3]{B}$	$\sqrt[3]{B_1}$	$\sin D$	$\sin D_1$	
		3	a	B	B_1	$\sin^{\frac{3}{2}} A$	$\sin^3 D_1$	
			b	B^2	B_1^2	$\sin^3 A$	$\sin^6 D_1$	
			c	$B^{\frac{2}{3}}$	$B_1^{\frac{2}{3}}$	$\sin A$	$\sin^2 D_1$	
			d	$\sqrt[3]{B}$	$\sqrt[3]{B_1}$	$\sqrt{\sin A}$	$\sin D_1$	
	Fifth Powers	10		Exactly as for line of cubes, substituting indices 5 for 3, and 10 for 6, where they occur.				

Face of stock	Slide	No		Proportions				Remarks
No 3	No 2	1		$\sin A$	$\sin A_1$	$\sin B$	$\sin B_1$	
Sin and Sin^2	Sine	2	*a*	$\sin D$	$\sin^2 D_1$	$\sin B$	$\sin B_1$	
			b	$\sin D$	$\sin D_1$	$\sqrt{\sin B}$	$\sqrt{\sin B_1}$	
		3	*a*	$\sin^2 D$	$\sin A_1$	$\sin B$	$\sin B_1$	
			b	$\sin^2 D$	$\sqrt{\sin A_1}$	$\sqrt{\sin B}$	$\sqrt{\sin B_1}$	
	Tangt	5		Exactly similar to Sine, substituting $\tan^2 B$ for $\sin^2 B$ in each case				
	No 3							
	Tangt	5		Exactly as for tangent, in slide No 2				
	6° to 84°							
	Tan^2	1	*a*	$\sin A$	$\sin A_1$	$\tan B$	$\tan^2 B_1$	
	6° to 45°		*b*	$\sqrt{\sin A}$	$\sqrt{\sin A_1}$	$\tan B$	$\tan B_1$	
		2		$\sin D$	$\sin D_1$	$\tan B$	$\tan B$	
		3	*a*	$\sin A$	$\sin^2 D_1$	$\tan^2 B$	$\tan^2 B_1$	
			b	$\sqrt{\sin A}$	$\sin D$	$\tan B$	$\tan B_1$	

It will be observed that all the combinations of each face of a slide with any stock are grouped under *three numbers*, and that although in some cases there are several sets of proportions grouped under a number, yet the proportions in each set are really one and the same, but differently expressed, *e. g*, it is apparent that the proportions $B^2 : B_1^2 :: A : A_1$, and $B : B_1 :: \sqrt{A} : \sqrt{A_1}$, are identical For each combination of slide and stock, there can be only three sets of proportions—1st, Two numbers on the upper part of the stock with two numbers on the slide, 2nd, Two numbers on the lower part of the stock with two numbers on the slide, and 3rd, One number on the upper part of the stock, one number in the lower part of the stock, and two numbers on the slide, or, expressed in a formula, the only three possible combinations are $A : A_1 :: B : B_1$, $D : D_1 :: B : B_1$, and $A : D_1 :: B : B_1$

A few examples of problems which may be solved on the improved rule, with some of the lines, are given.

1. Use of lines D and D.

Taking a similar example to VIII. of former article

A sâl beam, 11 feet span, carries a permanent uniform load of 3300 lbs Required its scantling, so that its deflection under the load may not exceed $\frac{1}{180}$ span. Ratio of depth to width to be $\sqrt{2}$ 1.

The rule as before explained is $\left.\begin{matrix} b \\ d \end{matrix}\right\} = \left\{\begin{matrix} 214 \\ 303 \end{matrix}\right\} \sqrt[4]{W L^2}$

to find $WL^2 = 398{,}000$, setting of slide rule is

$$\begin{array}{lll} A & 3300 & 398{,}000 \\ \hline D & 1 & 11 \end{array}$$

To find $\sqrt[4]{W L^2} = 25\ 1$, setting of rule is

$$\left\{\begin{array}{lll} A & & 398{,}000 \\ \hline & 1 & 25\ 1 \\ \hline D & 25\ 1 & \end{array}\right.$$

and the same setting gives the scantlings by simple inspection (without moving the slide) as 5 38″ × 7 63″

$$\left\{\begin{array}{llll} D & 1 & 214 & 303 \\ \hline D & 25\ 1 & 5\ 38'' & 7\ 63'' \end{array}\right.$$

The method explained of finding the fourth root of 398,000 is derived from the proportion given in table (slide D with face I, No 36)

$$A : D_1^2 :: B^2 : B_1^2$$

putting x for A and 1 for B_1^2 $\quad x : D_1^2 :: B^2 : B_1^2$

putting D_1 and B each $= N$ $\quad x : N^2 :: N^2 : 1$

consequently, $\quad x = N^4$

or, which is the same thing, $\sqrt[4]{x} = N$

Before attempting to extract the fourth root of any number, it must be decided how many integers are in the required root, and approximately, what its first figure is—pointing off 39,80,00 as for extraction of square root, it is clear that the square root is between 600 and 700, and that the square root of the square root is between 20 and 30, then set 1 on slide at about 24 on D, and it will be found that, two or three trials will give the exact root

Care must be taken that no mistake is made in this respect, for example, take the number 16 and find its fourth root, the slide rule will give four answers.

First			*Second*		*Third*		*Fourth*	
A		16		16	16		16	
D	1	1127	1	2	357	1	633	1
D	1127		2			357		633

each and all of these answers are correct,

for,	1 127	is the fourth root of			1·6
	2·	,,	,,	,,	16 0
	3 57	,,	,,	,,	160 0
	6·33	,,	,,	,,	1600 0

hence the necessity for pointing off the number whose fourth root is required, and also for finding an approximation to the first significant figure of the root before attempting to find the root itself. The same remarks will apply to the use of the cube and fifth-power slides.

2 Use of the cube and fifth-power slides with lines A and D

(Refer to page 228, Neville's Hydraulics, 2nd Edition) Find dimensions of a channel, slope 18 inches per mile, to discharge 200 cubic feet per second.

Assume a width of 20 feet and a depth of $2\frac{1}{2}$ feet, then hydraulic mean depth $= r = \frac{20 \times 2{\cdot}5}{20 + 5} = \frac{50}{25} = 2.$

Slope $= \frac{1{\cdot}5}{5280} = S = {\cdot}000284$, found by slide rule,

and $r\,s = {\cdot}000568$

velocity $= v = 140\sqrt{r\,s} - 11\sqrt[3]{r\,s}$

B	1	000568	found by simple inspection on the slide rule.	$140\sqrt{r\,s} = 3\ 335$
D	144	3 335		$11\sqrt{r\,s} = 0\ 912$
Cubes	1	000568		$v = \overline{2\ 423}$
D	11	912		

and discharge $= 50 \times 2\ 423 = 121{\cdot}15$ cubic feet per second.

Then we have—

$$r^{\frac{5}{2}} : R^{\frac{5}{2}} : d \,.\, D$$

$$\text{or } 2^{\frac{5}{2}} \,.\, x^{\frac{5}{2}} \,.\, 121{\cdot}15 \,.\, 200$$

A	$2 = r$	$2\ 44 = x$
Fifth Powers	$121\ 15 = d$	$200 = D$

and 2·44 is the required hydraulic mean depth.

Putting b = width of channel, and d = its depth, $b \quad d \quad 20 \quad 2\ 5$,

and $r = \dfrac{\text{area}}{\text{wetted perimeter}} = \dfrac{b\,d}{b + 2\,d} = 2{\cdot}44$

From these equations, it is found that $b = 24\ 4$, and $d = 3{\cdot}05$, and it may be proved by calculation that the discharge of such a channel would be almost exactly 200 cubic feet per second.

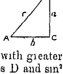
It will be seen by this example that hydraulic problems of some complexity can be solved with ease, accuracy and rapidity, by the improved slide rule

Two rules should be employed in working out questions, such as the above, one rule arranged ADD, and the other A_1 cubes D or $A_1 \left\{ \begin{array}{c} \text{Fifth} \\ \text{Powers} \end{array} \right\}$ D, otherwise, if only one rule be used, it will be necessary to shift the slides repeatedly.

USE OF THE TRIGONOMETRICAL LINES FOR SOLVING PLANE TRIANGLES.

Right-angled triangles, c being the hypothenuse

Given $B = 35°$, $c = 45$ feet.



$\dfrac{\text{sine}}{\text{BC}} \quad \dfrac{1 = \text{radius}}{45 \text{ feet}} \quad \dfrac{B = 35}{25\ 8 = b} \quad \dfrac{90 - B = 55°}{36\ 75 = c}$ $\left\{ \begin{array}{l} \text{or, can be solved with greater} \\ \text{accuracy with lines D and sin}^2 \end{array} \right.$

Given $B = 27°$, $a = 62$

$\left\{ \begin{array}{lll} \text{B C} & a = 62 \text{ feet} & b = (31\ 5)^2 \\ \hline \text{tan} & 45° = \text{rad} & B = 27 \end{array} \right.$ can be obtained with greater accuracy by lines tan² and D.

$\left\{ \begin{array}{lll} \text{sin} & 90° - B = 63 & 90° = \text{rad} \\ \hline \text{B C} & a = 62 \text{ feet} & c = 69\ 8 \end{array} \right.$ or $\sqrt{62^2 + 31\ 5^2} = 69\ 8 = c$

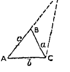
Given $c = 70$, $a = 45$.

$\left\{ \begin{array}{llll} \text{sin} & 90° = \text{rad.} & A = 40° & \text{and } B = 50° \\ \hline \text{A B} & c = 70 & a = 45° & b = 53\ 5 \end{array} \right.$ or lines D and sin² can be used.

Given $a = 45$ feet, $b = 53\ 5$ feet, $c = 70$ feet.

$\left\{ \begin{array}{llll} \text{sin} & 90° = \text{rad} & 40° = A & 50° = B° \\ \hline \text{A B} & 70 = c & 45 = a & 53\ 5 = b \end{array} \right.$

Oblique Triangles



Given $\begin{array}{c} A = 35°\ B = 50° \\ a = 52 \text{ feet} \end{array}$, $C = 180'' - (A + B)$,
$= 95°$

sin	A = 35°	B = 50°	180° − C = 85°
A B	a = 52 ft	b = 69.5 ft.	c = 90′

Had C been less than 90°, C would have been used instead of 180 − C, to point out the side c

or, more accurately,

D	a = 52	69.5	c = 90.2
sin²	A = 35°	B = 50	180 − C = 85°

C being obtuse.

Given a, b and C, as in the last example, by successive trials place such a number under 85° that the sums of the angles over a and b shall be = 85°, and the final setting will be as above

Given a = 80, b = 65, C = 70°, C being acute By successive trials, place such a number under C that the sums of the angles over a and b shall equal 180 − c = 110°

sin	B = 46° 30′	A = 63° 30′		C = 70°
A B	b = 65	a = 80	84 by trials	feet

Given a = 30 feet, b = 90 feet, C = 50°, in which case B will evidently be an obtuse angle, it will now be found impossible to obtain two angles whose sum = 180° − 50° = 130° by proceeding as in last example, for

Place	100	under	50°	under	90°	is found	43° 30′	under	30°	is found	13° 20′	sum 56° 50′
Again	90	„	50°	„	90°	„	50°	„	30°	„	14° 40′	„ 64° 40′
„	80	„	50°	„	90°	„	60°	„	30°	„	16° 40′	„ 76° 40′
„	69	„	50°	„	90°	„	90°	„	30°	„	19° 30′	„ 109° 30′

and no answer at all is obtainable, if any number less than 69 be placed under 50°, as 90 will extend beyond the scale

In all such cases, place such a number under C that the *difference* between the angles over a and b shall equal C, then the lesser angle is one of the required angles, and the difference between 180 and the second angle is the remaining angle.

D	c = 74.5 by trial	a = 30	b = 90
sin²	C = 50°	A = 18°	B = (180 − 68°) = 112°

The first trial in this case was 100 over 50° which gave 90 over 43° 30′, and 30 over 13° 20′, difference, 30° 10′.

The second trial was 70 over 50° which gave 90 over 82° and 30 over 19° 20′, difference 62° 40′

It then appeared that the required number was between 100 and 70.

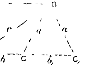
Next trial was 75 over 50° which gave 90 over 67° and 30 over 18°, difference 49°.

and on placing 71.5 over 50, as shown above the required answer was obtained

Given $a = 35$ feet, $c = 60$ feet, $A = 30°$

$$\left\{\begin{array}{lllll} \dfrac{D}{\sin^2} & \dfrac{a = 35 \text{ ft}}{A = 30°} & \dfrac{c = 60 \text{ ft}}{C = 59°} & \dfrac{b = 69.9 \text{ ft}}{B = 180° - (30° + 59°) \text{ use } 91° \text{ to}} \\ & & & = 180° - 89° \text{ find } b \end{array}\right.$$

$$\left\{\begin{array}{lllll} \dfrac{\text{or } D}{\sin^2} & \dfrac{a = 35 \text{ ft}}{A = 30°} & \dfrac{c = 60 \text{ ft}}{C = 180° - 59° = 121} & \dfrac{b = 31.5 \text{ ft}}{B = 180 - (30° + 121)} \\ & & & = 29° \text{ which use} \\ & & & \text{to find } b \end{array}\right.$$



Given $a = 30$ $b = 40$ ft. $c = 45$ ft

$$\left\{ \dfrac{D}{\sin^2} \quad \dfrac{a = 30 \text{ ft}}{A = 40° 50'} \quad \dfrac{b = 40 \text{ ft}}{B = 60° 10'} \quad \dfrac{c = 45 \text{ ft}}{C = 78° 50'} \right.$$

by successive trials make the sum of the angles under a b c equal to 180°

Given $a = 30$, $b = 35$, $c = 60$

In this case it will be seen at once on placing 60 ft against 90°, that the above method will fail, for 90° + 35° 40′ + 30° = 156 40′ and if 60 be placed against any angle below 90° the sum of the angles will be still further reduced. The rule is, where as in this example, one of the required angles is obtuse, to make the sum of the two smaller angles equal to the greater angle, then the supplement of this last angle and the two smaller angles are the three required angles.

$$\left\{ \dfrac{D}{\sin^2} \quad \dfrac{a = 30 \text{ ft}}{A = 20° 40'} \quad \dfrac{b = 35 \text{ ft}}{B = 24° 20'} \quad \dfrac{c = 60 \text{ ft}}{C = (180 - 45°) = 135°} \right.$$

USE OF THE TRIGONOMETICAL LINES IN SOLVING SPHERICAL TRIANGLES

Right-angled spherical triangles.

A few examples likely to be useful to an Engineer are given. They are all, except that for graduating a sun-dial, taken from Bayley's Hand-Book of the "Double" Slide Rule

Amplitude

$$\text{Sin amplitude} = \frac{\text{sin declination}}{\text{sin co-latitude}}$$

Required amplitude of sun Latitude 18° 21′ N. Declination 16 S
Co-latitude = 41° 39′. Amplitude = 24° 30′.

$$\left\{ \dfrac{\sin}{\sin} \quad \dfrac{16° = \text{dec.}}{41° 39'} \quad \dfrac{24° 30' = \text{amp}}{90° = \text{radius}} \right.$$

If the compass bearing at sunset was W. 28° S′ the variation is 3° 30′ E.

This is the simplest method of ascertaining the variation of a prismatic compass. Take the bearing of the sun at sunrise or sunset, when the lower limb just touches the horizon, and find the true bearing by the above

rule The difference gives the variation, which as a prismatic cannot be read to less than 20′, will be found with sufficient accuracy

Ascensional Difference

When latitude and declination are of the same name, add ascensional difference to 6 hours *for time of setting and subtract for rising—if of* different names, subtract from 6 hours for setting and add for rising, the result gives the *apparent* time of sunrise or sunset, to which the equation of time must be applied to reduce it to mean time

$$\text{Sin asc. diff.} = \text{tan lat} \times \text{tan declination}$$

Should lat. exceed 45° this should be read

$$\text{Sin asc. diff} = \frac{\text{tan decl}}{\text{tan co lat}}$$

Latitude 31° 10′ N., and declination 11° 14′ S, required sun's ascensional difference

$$\left\{\begin{array}{lll} \text{sin} & 6^\circ\,54' = \text{ascen diff} & \\ \hline \text{tan} & 31^\circ\,10^\circ = \text{lat} & 45^\circ = \text{radius} \\ \hline \text{tan} & & 11^\circ\,14' = \text{decn} \end{array}\right.$$

6° 54′ reduced to time becomes $0^h\ 27'\ 36''$

and sun rises at $6^h\ 27'\ 36''$ and sets at $5^h\ 32'\ 24''$

Again, find ascen diff in lat 51° 31′ N. Sun's decn being 20° N.

$$\left\{\begin{array}{lll} \text{sin} & 27^\circ\,15' = \text{ascen diff} & 90^\circ = \text{radius} \\ \hline \text{tan} & 20^\circ = \text{decn} & 38^\circ\,29' = \text{co. lat. } 51^\circ\,31' \end{array}\right.$$

ascen. diff 27° 15′ converted into time becomes

$$\left.\begin{array}{rl} 27^\circ = & 1^h\ 4 \times 12'\ 0'' \\ = & 1^h \quad\ 48'\ 0'' \\ 15' = & 0 \qquad\ 1\ 0'' \end{array}\right\}\ 27^\circ\ 15' = 1^h\ 49'$$

and sun rises at $6^h\ 0'\ 0'' - 1^h\ 49'\ 0''$ or at $4^h\ 11'\ 0''$

and sun sets at $6^h\ 0'\ 0'' + 1^h\ 49'\ 0''$ or at $6^h\ 49'\ 0''$

This is a particularly convenient method of getting the correct time when out in camp, or at an out-station It is only necessary to note the moment either at sunrise or sunset when the lower limb of the sun just touches the horizon, and the correct time may be found to within certainly 15 seconds of the truth by the above rule in a level country, far more accurately than by the best universal sun-dial

Twilight when shortest.

We have to find at what declination of the sun the twilight is shortest, and then refer to the almanac for the day.

Sin declination = sin lat. × tan 9°

In the latitude of Madras, 13° 4′ N, when will twilight be shortest?

$$\begin{cases} \sin & 2^\circ\ 3' = \text{decn} & 13^\circ\ 4' = \text{lat} \\ \tan & 9^\circ = \text{constant} & 45^\circ = \text{radius} \end{cases}$$

Since latitude is North declination will be South, and in 1868, the dates were September 27th, 28th, and March 14th, 15th.

Duration of shortest twilight.

$$\text{Sin}\ \frac{\text{duration}}{2} = \frac{\sin\ 9^\circ}{\sin\ \text{co-lat}}$$

What is the *duration* of the shortest twilight at Madras?

$$\begin{cases} \sin & 9^\circ = \text{constant} & 9^\circ\ 15' = \text{half duration} \\ \sin & 76^\circ\ 56' = (90^\circ - \text{lat}) \text{———} & 90^\circ = \text{radius} \end{cases}$$

Duration $= 18^\circ\ 30^\circ$ or $18' = 1^h + 4 \times 3 = 12' = 1^h\ 12'\ 0''$

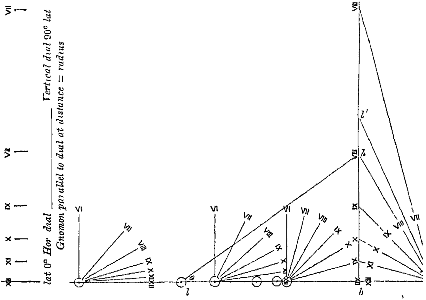
$30' = \quad \ldots \quad \ldots \quad . \quad 0\ \ 2'\ 0''$

or duration = 1 hour 14 minutes

9° is taken as the constant, because twilight ceases when the sun is 9 degrees below the horizon.

To graduate a Sun-dial

Tangent Reduced Hour angle = Sin. Lat × Tan H A



Horizontal dial Lat 15° 30° 45° 60° 90° angle of gnomon with dial =
Vertical „ Lat 75° 30° 45° 30° 0° angle of gnomon with dial =

The gnomon always points to the elevated pole and is parallel to the axis of the earth.

The geometrical construction is given in the figure

Strike a quadrant *abc*, with any convenient radius, and produce *ab* indefinitely towards *l*, divide the quadrant into hours half hours, and so on, as shown in figure, and mark off their tangents on the vertical line bl' Also lay off the angle bal = latitude for vertical dials and = $(90° - \text{latitude})$ for horizontal dials Lay off the secant or cosecant al' from b to l, and draw lines from l to the various tangents on bl, these lines will be the reduced hour lines for the latitude The lines have been laid off and marked for latitude 0°, 15°, 30° and 90°, both for vertical and horizontal dials in the figure The centres for latitude 45° and 60° are also marked.

The mathematical proof of this construction is sufficiently simple. $al' = bl = \text{cosec } cal = \text{cosec lat}$, $bh = \tan hab = \tan$ any hour angle $= \tan$ HA

Then $\tan\theta = \tan$ reduced hour angle $= G\ \frac{bh}{bl} = \frac{\tan \text{HA}}{\text{cosec lat}} =$

$\tan \text{HA} \times \sin \text{lat}$, which equation is the formula given above for horizontal dials. For vertical dials, the equation is $\tan\theta = \text{HA} \cos \text{latitude}$

The locus of l for latitude 0° in horizontal dials, and latitude 90° in vertical dials, is infinitely distant, and the hour lines are drawn parallel to the 12 o'clock line In practice, if it is desired to graduate a dial with extreme accuracy, the cosecant bl and the tangents bh are to be laid off from a table of natural sines and tangents by an accurate scale of equal parts.

This construction is the same in principle as that given by "H" in page 108, Vol IV, "Professional Papers." A proof is given below; the letters refer to the letters given in his diagram

$$\frac{dA}{AB} = \tan\theta = \tan \text{ reduced hour angle}$$

$$\frac{dA}{Ad'} = \tan \text{HA} = \frac{dA}{AD} \qquad \frac{AD}{AB} = \sin \text{latitude}.$$

$$\text{hence, } \tan \text{HA} \times \sin \text{latitude} = \frac{dA}{AD} \times \frac{AD}{AB} = \frac{dA}{AB} = \tan\theta;$$

also $\frac{AB}{AD}$ = cosec latitude, or, AB = cosec latitude to radius $AD = Ad''$

The reduced angles are given by the slide rules as follows.—

Put in extra tangent slide — Find reduced angles for latitude 27°

sin 27° = latitude					
tan 45° = radius	15°	30°	45°	60°	65° 30'
tan reduced hour angles	6° 58' I or XI.	14° 45' II or X	24° 30' III or IX	38° 20' IV or VIII	45°

for reduced hour angles above 45° invert the slide, and read the complements on the lower line.

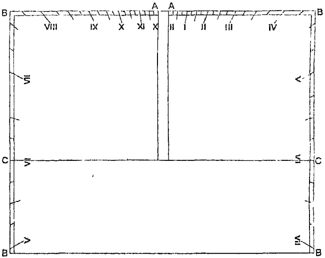
sin		
tan 65° 30'	75°	
tan 45°	30° 30' = (90 − 59° 30') V or VII.	

If it be desired to graduate the dial to 5 minutes, or spaces of $\frac{15^\circ}{12} = 1^\circ$ 15', the ordinary tangent slide must be used instead of the extra slide for the first and last half hours, thus—

sin			27° = latitude
tan	1° 15'	2° 30'	45° = radius
tan	0° 34' 12h 5' 11h 55'	1° 8' 12h 10' or 11h 50'	

and

sin			
tan	24° 30' = 90° − 65° 30'	2° 30' = 90 − 87° 30'	1° 15' = 90° − 88° 45
tan	45'	5° 29' = 90° − 84° 31' 5h 50' or 6h 10'	2° 44' = 90° − 87° 12' 5h 55' or 6h 5'



A dial could not, however, be laid down either conveniently or accu-

rately by the angles unless a large cucular protractor with vernier and arms were used, and the lines can be laid down far more conveniently and rapidly by scale and compass as follows —

Take any convenient radius (322 from the $\frac{1}{4}$-inch diagonal scale on the ordinary 6-inch ivory protractor has been taken in the diagram) and construct a pair of parallel squares, sides equal to this radius, with a space between them equal to the thickness decided on for the gnomon as in the diagram, find the cosecant of the latitude by the slide rule, thus—

C	2 2 = cosec lat
$\sin^2$	27° = lat

Then find $\dfrac{\text{radius assumed}}{\text{cosec lat}} = \dfrac{643}{2\ 2} = 2923 =$ reduced radius,

or find reduced radius at once by slide rule, thus—

C	643 = { radius assumed	292 = { radius reduced	Set 45° on extra line of tangents to 292 on line A
$\sin^2$	27° = lat.	90° = radius	

A	292	782	1 693	2 92	5 06	10 92	6 43
tan	45° rad	15°	30°	45°	60°	75°	65 35
		I	II	III	IV.	V	
		XI.	X.	IX	VIII	VII	

These distances, *i. e*, 782, 1 693, 2·92, &c, laid off as tangents from A towards B, give the hour lines. To lay off the cotangents from C—find a second reduced radius.

C	643	1415	Invert extra line of tangents and set 45° against 1415 on line A
$\sin^2$	5° 44½′ = 10 + radius	27° = lat	

A	1415	643	5 84	3 77	1 86
tang	45° = rad	65° 35′	67° 30′	75	82° 30′
			IV 30′	V.	V 30′
			VII 30′	VII	VI 30′

and these distances 5 84, 3·77, 1 86, laid off from C towards B give the remaining hour lines It will be observed that the reduced tangent and cotangent for 65° 35′ are equal to each other and to radius The reason of this is, that tan 65° 35′ × sin 27° = tan 45°, and this equality forms a check on the correctness of the setting of the slides

Use of the Trigonometrical Lines in Solving Spherical Triangles

Oblique Spherical Triangles.

Solved with lines sin and $\sin^2$ on stock, and line sin on slide The examples are taken from Bayley's "Hand-book."

A is the angle sought, a the opposite side, and h = half sum of the three sides

Example—In latitute 36° 40', N, the zenith distance of a star was 66°, and polar distance 76° 10', required the hour angle

$$\begin{aligned} a &= \text{zenith distance} &&= 66^\circ\ 0' \\ b &= \text{polar distance} &&= 76^\circ\ 10' \\ c &= \text{co-lat} &&= 53^\circ\ 30' \\ h &= \frac{a+b+c}{2} &&= 97^\circ\ 50' \\ h - b &= 21^\circ\ 40' && \\ h - c &= 44^\circ\ 20' && \end{aligned}$$

Formula is $\sin\frac{1}{2}A = \sqrt{\dfrac{\sin(h-b)\times\sin(h-c)}{\sin b \times \sin c}} = \sqrt{\dfrac{\sin(h-b)\times\sin(h-c)}{\sin\phi}}$

$\sin\phi = \sin 51^\circ\ 20'$ found thus $\left\{\begin{array}{lll} \sin & 51^\circ\ 20' = \phi & 76^\circ\ 10' = b \\ \hline \sin & 53^\circ\ 30' = c & 90^\circ = \text{rad} \end{array}\right.$

and $\frac{1}{2}$ A is found as follows :—

$$\left\{\begin{array}{lll} \sin & & 44^\circ\ 20' = h - b \\ \hline \sin & 21^\circ\ 40' = h - c & 51^\circ\ 20' = \phi \\ \hline \sin^2 & 35^\circ\ 5' = \frac{1}{2}\text{ A} & \end{array}\right.$$

hence $A = 70^\circ\ 10'$

$70^\circ = 4^h + 10' = 4^h\ 40'$

$10' = 0' + 10 = 0\ \ 0'\ \ 40''$

$4^h\ 40'\ 40''$

and hour angle $= 4^h\ 40'\ 40''$

correct hour angle is $4^h\ 40'\ 46''$

$$\begin{aligned} \text{Again}\quad a &= \text{zenith distance} &&= 66^\circ\ 6' && \\ b &= \text{polar distance} &&= 84^\circ\ 26' && h - b = 26^\circ\ 41' \\ c &= \text{co-latitude} &&= 71^\circ\ 42' && h - c = 39^\circ\ 25' \\ h &= \frac{a+b+c}{2} &&= 111^\circ\ 7' && \phi = 71^\circ\ \text{(by slide rule)} \end{aligned}$$

$$\left\{\begin{array}{lll} \sin & & 26^\circ\ 41' = h - b \\ \hline \sin & 39^\circ\ 25' = h - c & 71^\circ = \phi \\ \hline \sin^2 & 33^\circ\ 20' = \frac{1}{2}\text{ A} & \end{array}\right.$$

the exact value of $\frac{1}{2}$ A is 33° 19' 11·5"

The azimuth is found in a similar manner.

The arrangement of the lines, as described above, is not quite so convenient as it might be made, and the three-slide rule is decidedly inconvenient in use as it will not lie flat on a table If a single rule only be wanted, the two-slide rule will be found very convenient and useful, and the third line on the three-slide rule for working out oblique triangles, would probably be seldom or never required. If, however, this line be a

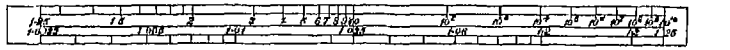
sine quâ non, it should be ordered on a *second* two slide rule, and the best possible arrangement of the lines would probably be as follows —

Face of stock—upper line, sines, lower line, sines squared.

Slide—face, sines, and back, tangent squared, to work with line of sines squared or with line D on the ordinary two slide rule. Back of Rule—stock—upper and lower lines A (arithmetical line), and on the slide, a set of lines for obtaining any power or root of a number at sight, whether whole or fractional. This latter line would read on one face from 1 0025 to 1 25 on the lower edge, and from 1 25 to 10^{10}, or ten thousand millions on the upper edge, it is constructed by laying down the logarithms of the logarithms of numbers

Thus log 1·25	= 097	and log 097	$= \bar{2}$ 987		10 is taken as the origin of the scale and is placed in the centre of upper line of, slide, and the general arrangement of the lines is as sketched below
„ 1 30	= 114	„ 114	$= \bar{1}$ ·057		
„ 1 50	= 176	„ ·176	$= \bar{1}$ 246		
„ 1 025	= 0107	„ 0107	$= \bar{2}$ 010		
„ 1 0025	= 0010844	„ ·0010844	$= \bar{3}$ 035		
„ 10,000,000,000	=	„ 10 10	= 1		

The distances given in last column where laid down from a scale of equal parts.



The distances are the same from 10^{10} to 10 as on the ordinary rule, 10^2 being the same as 2, and so on, To take an example—Find 9th root of 1 2, stretch from 10^9 in a pair of compasses, and measure this distance backward from 1 2 and 1 02 is reached, which by reference to a table of squares and cubes is found to be almost exactly the required root. Readings below 3·3 are obtained in this scale with far greater accuracy than on the line A, not so above 100, when the results are of little practical value Powers above ten may however be obtained more correctly, thus—Find 7th power of 12; $12^7 = 10^7 \times 1\ 2^7$, $1\ 2^7$ would be obtained by the rule = 3 573, and hence 12^7 = 35,730,000, a useful approximation.

The arrangement of the lines of the two-slide rule at first described would be improved, by omitting the square slide with cubes on face and extra line of tangents on back, and in its room providing two spare slides, one with cubes and fifth powers as for the three-slide rule, and the second with the ordinary arithmetical lines BC on face and the extra line of

tangents on back; there would thus be two independent slides with the BC lines This arrangement would be found very useful in calculations connected with the strains in timber framing, as it is inconvenient, for example, after having found the weight on a truss by the line AB to be obliged to shift the BC slide to the sine-tangent side of the stock, for the purpose of taking out the strains, and again to shift the slide back to the AD side for working out the scantlings. If a second AB slide were available, this inconvenience would be obviated. To conclude, the arrangement of lines found best by the writer is as follows, and he would recommend any one who may feel inclined to obtain the rules from Elliott, Brothers, to request them to adopt it.

	Stock	Slide
Two-slide rule	*Face* —Lines A and D.	*Face* —BC *Back* —D
	Back —Lines sine and tangent	*Face* —Sine *Back* —Tangent,
		SPARE SLIDE I.
		Face.—Cubes *Back* { Fifth powers
		SPARE SLIDE II
		Face —BC *Back* { Extra tangent
Extra two-slide rule	*Face* —Sine and sine squared.	*Face* —Sine
		Back —Tangent squared.
	Back —A and A	*Face* —Powers 1 0025 to 10^{10}.
		Back —Powers 100000025 to 1 0025.

LUCKNOW,
16*th January*, 1869.

W. D. M

No. CCXXVI.

CEYLON VILLAGE TANKS.

Memorandum by GUILDFORD MOLESWORTH, ESQ., *Chief Engineer.*

IT is the peculiarity of most of the Village Tanks in Ceylon that they are formed in valleys, the bottom of which is almost always a dead level or nearly so in cross section, and the sides are formed of high ground of cabook (laterite) which runs out in small spurs into the valley, forming bays nearly on the same level with the rest of the valley.

These valleys, when not dammed up, are, if water be procurable, cultivated with paddy. The tank is formed by throwing an embankment across from a spur on one side to a spur on the other side of the valley. The tanks so formed vary from 5 to 20 acres in extent, and from 6 to 10 feet in depth.

As a general rule, they have neither sluice nor spill water, and the only means of letting out the water for irrigation purposes is by cutting a breach in the embankment, but this expedient, apart from the wasteful expenditure of water it entails, for want of proper regulation frequently leads to the loss of the whole of the water stored, and to the failure of the crops, for the rush of water very often overpowers the efforts of the villagers to close the breach and a large portion of the embankment is carried away, so that the villagers not only lose the crop that season, but become discouraged and frequently lack the energy or the means to effect the repairs necessary to store the water for the ensuing crop.

To remedy this evil, as far as possible, I have designed a small iron village sluice of simple character, which may be built into the masonry without the aid of skilled labor, and of such a size that the water cannot well be wastefully used and is capable of easy regulation.

Instead of inserting these sluices (according to the usual practice) in the centre of the embankment, where the foundation is soft and bad, I generally select the spur or high ground, which is usually of *cabook* of such a consistency that a channel may be cut with sides nearly vertical, and across this channel I build a short wall of brick-work or masonry and bed the iron work of the sluice in it In some cases the inner face of the masonry is rendered in cement to prevent percolation.

By placing the sluice in the high ground away from the embankment, there is no chance of the embankment being breached by any leak or discharge from the sluice or masonry, the sluice channel is under control, the masonry in firm foundation—the iron work and masonry readily inspected—the sluice, being only 4 feet 6 inches in length, is easily cleared of any obstruction. The sluice channel at its outlet can be dammed up with a couple of loose planks, which can be removed when the water is low in the tank, but which are useful when the head is great, in neutralizing, by the back water they form, the destructive rush of water from the sluice.

It is sometimes desirable, when there is an accumulation of dead leaves or sticks in the tank, to insert into the sluice channel, between the tank and the sluice, a screen of hurdle or rough wattle, to prevent an accumulation of these substances in front of the sluice.

Should the sides of the valley be higher than the middle, a channel can readily be made by taking out the earth necessary for the repairs or construction of the embankment in such a manner as to form it.

The spill water is generally cut in the high ground above the sluice channel.

The accompanying sketch shows the general character of village tanks formed in this manner

AA being the embankment.
BB the sluice channel,
C the sluice.
D the spill water.

Sketch of Village Tank

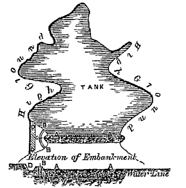


Plate XVI. shows the general view of the sluice and masonry, *Plate XVII* the details of the iron work

The sluice is generally 8 inches in diameter, which, with the head of 2 feet will (roughly speaking) irrigate about 100 acres of land at a rate of $1\frac{1}{2}$ cubic foot per minute per acre, or 150 acres at 1 cubic foot per minute per acre.

The sluice is cast in one piece with a pipe 4 feet 6 inches long, so as to extend well through the masonry, the opening is of gridiron form, thereby necessitating only a short stroke, and obviating the necessity for projecting lugs or guides which are apt to get broken off in transport The ports are widened out so as to give an area equal to the pipe

The form originally designed was that of the "vena contracta," but as some practical difficulties and increased expense would be entailed by this form (in coring out the moulding and fixing it in the sand), I adopted the square box necking shown in the drawing, which, though it gives a lower co-efficient of discharge, is more simple in construction and more easily bedded in the masonry.

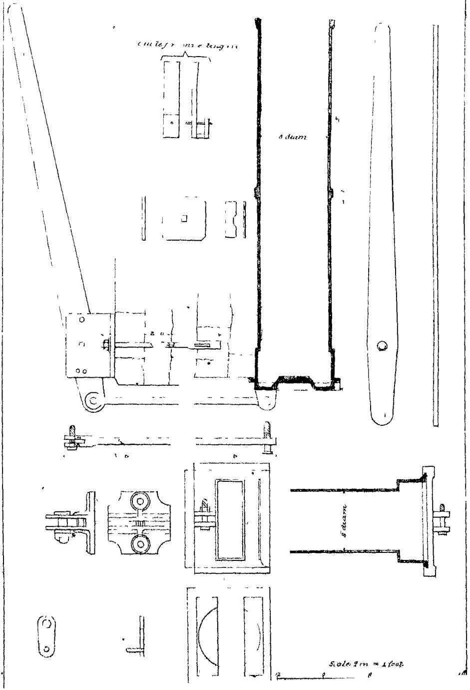
The cover is also of cast-iron and forms its own guide sluice, both the cover and the sluice are capable of being easily faced up by machine, and they are put together without bolts of any kind The cast-iron does not suffer from oxidation, and the only portion of wrought-iron are the handle rod and bolts connected therewith The only portion of wrought-iron under water is one bolt and a portion of the rod. The whole is of the most simple character, and it is almost impossible that it should get out of of order

I have preferred the use of a simple lever-handle to the use of the screw to raise the sluice valve, because the screw being left to rust in village tanks, which are seldom under inspection, is apt to get out of order when the tanks are out of use.

In case it is desired to prevent any tampering with the sluice by letting

CEYLON VILLAGE TANKS

(Cast-iron Sluices for Irrigation purposes)



off the water at times when it should be reserved, or by closing it at night when the fields are under irrigation, I have designed a simple locking apparatus by lengthening the washer of the pin on which the handle turns and rivetting on to it a small pin which passes through holes in the bracket as well as through the handle and fixes it in different positions, and a padlock (passing through the cotter which secures the washer) prevents its being moved

The ends of the bolts which fasten the rod are also rivetted over the nuts to secure them

The key of the padlock is entrusted to the village headman, or other person responsible for the distribution of the irrigation water.

G. W

No CCXXVII.

BUILDING STONE IN WESTERN INDIA.

Report on the different localities visited, in 1866, with a view to obtaining stone for the Kurrachee Harbor Works. BY LIEUTENANT MEREWETHER, R.E., *Executive Engineer.*

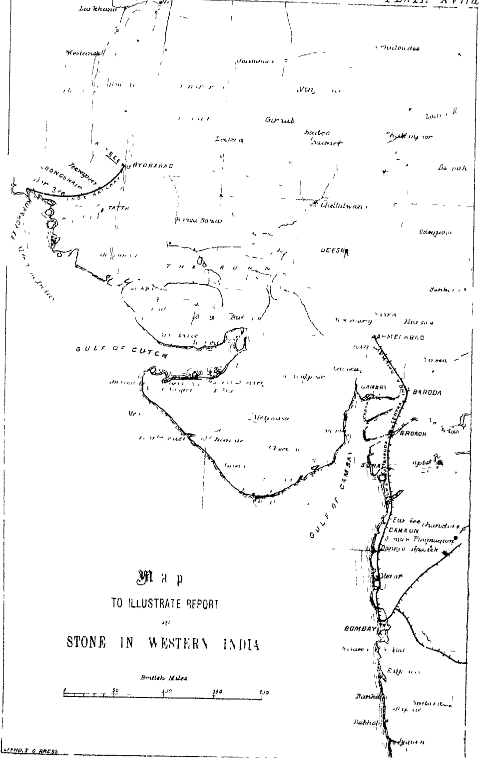
IN October 1864, an estimate of the probable cost of carrying out the proposed breakwater was submitted by me, and in it provision was made for the use, in the facing of the end and of the more exposed side, the paving, and other portions on which the Monsoon Sea would break with the greatest violence, of hard gray sandstone from within half a mile of the Joongshaie Station on the Sind Railway Company's line

Stone from Joongshaie for the proposed work would probably be carried by rail to the Native Jetty at Kurrachee, about 55 miles, and thence by water $4\frac{1}{2}$ miles to the work, or in all about $59\frac{1}{2}$ miles

The estimate above referred to provided for the use of stones in the exposed portions, weighing up to rather more than two tons, and such it was considered could be obtained without very great difficulty from Joongshaie.

Mr. Price, however, on his return to India last year, was of opinion, from what he had then lately seen when visiting the great Harbour Improvement Works in Europe, that stones far larger than those specified by me would be necessary. He considered that no stone weighing less than 10 tons should be used in the more exposed portions of the Breakwater—of these about 1,760 would be required

Accordingly, soon after his return to Kurrachee, application was made to Government for me to be allowed to visit certain localities where it was thought that stone of the size above mentioned, of suitable quality and within a reasonable distance of the sea, might possibly be found.


HYDRABAD
TATTA
THE RUNN
GULF OF CUTCH
DEESA
AHMEDABAD
CAMBAY
BARODA
BROACH
SURAT
GULF OF CAMBAY
BOMBAY
Map
TO ILLUSTRATE REPORT
STONE IN WESTERN INDIA
British Miles
50
100
150
200

Were I only to mention the places visited from which stone of the size required could be obtained, this Report would be very short; but I think it desirable, in order to prevent the possibility of the supposition hereafter that sufficient search had not been made, that I should mention also those which I tried without success, and the best plan will be probably to give the detailed information in the form of a Diary, mentioning only those points which relate to the special object of my search, and at the end to give the general results in a short summary

A small map accompanies, on which are shown some of the principal places visited

On the 22nd March I left Kurrachee for Joongshaie, and on the following morning, for the third time, examined the stone near that place, and was strongly impressed with the difficulty and excessive cost of obtaining stones of 10 tons weight and upwards from that neighbourhood, even if they could be obtained at all, which appeared to me extremely doubtful. I then went on to Tatta—11 miles.

24th March—From Tatta to Soojawul-ka-Gote—18 miles.
25th „ To Mugribeem—21 miles
26th „ To Veer—24 miles
27th „ To Luckput (Cutch)—30 miles.

Between Joongshaie and Luckput there was nothing of interest in connection with the object of my search The limestone of which some of the tombs at Tatta are built has worn well, but it is not likely that, even if it could be obtained of sufficient size, it would stand the break of the Monsoon Sea in the position in which we should require to put it.

At Luckput I examined the fort, which is of considerable extent It is built partly of the nummulitic limestone on which it is founded, but for the most part of dark red and purple breccia, very similar to what I afterwards saw in the neighbourhood of Korah, 14 miles S E. of Luckput I was informed that this stone was brought from a place called Gooneree—6 miles distant It has worn tolerably well. I examined also a tomb which a Peer was building within the fort. He was using for it hard red stone, like that of which much of the fort is built, from a place towards Korah and eleven miles distant I saw 5 or 6 stones which had been brought in for this work, each of which weighed about 1½ ton. I was told that it was with very great difficulty and expense that these

had been obtained, that the stone was below the surface of the surrounding ground, and that no face could be obtained Even should stone, such as required for the Manora Breakwater, be obtained under otherwise favorable circumstances in this neighbourhood, its distance from the sea would render it very costly.

29th March.—To the Baboa hill, particularly mentioned in Captain Grant's "Geology of Cutch," as showing clearly the igneous action which has taken place in so many places in this neighbourhood. Thence to Punandrow and Godathur—21 miles After passing Baboa hill saw many fragments of dark green trap lying on the surface. None, however, exceeding about 2 cubic feet in size

Captain Grant says that Baboa hill is 3 miles from Ukri, but on his Map shows it as $4\frac{1}{2}$ miles The former is apparently right, i e, Ukri is about $1\frac{1}{2}$ miles north of its position as shown on Captain Grant's Map.

30th March.—To Mendiaree, Sunandrow, Mittoree, Korah and Mhurr—23 miles. The ground as far as Korah covered with pieces of dark green and purple trap, but none exceeding 3 cubic feet.

In the bed of a river close to Sunandrow saw large blocks of conglomerate and pieces of trap, as on higher ground adjoining Further on, a river winds round a mass of columnar basalt, the sides of which do not however, exceed nine inches—crossed a range of low hills between Mendiaree and Sanundrow which appeared to be entirely of trap, but it is composed of blocks of small size

From about 1 mile short of Korah as far as Mhurr, or for about 10 miles, low hills run along close to the road, particularly on the left hand side These are capped with large blocks of crystalline limestone. The largest which I could find was about 9 feet long by 4 feet wide by 2 feet deep, or, say, it weighed about 5 tons It was, however, not sound, and though hard, the texture of the stone appeared to me too coarse to stand much friction. The ground in this neighbourhood is so broken up by volcanic action that the earthwork required for a line of railroad to the sea would be very costly; one succession of heavy cuttings and embankments being necessary. Near Mhurr is obtained a very hard dark purple sandstone, of which are made grindstones.

31st March.—To Badria, Teyrah and Koratea—21 miles At Teyrah is a large fort which is being added to and strengthened by a brother of His Highness the Rao of Cutch, who lives there. The stone of which it

is built, and that generally in the immediate neighbourhood, is not of a nature to answer for the Manora Breakwater

April 1st.—To Bachunda, Betearee, Rawa, Mootarea, Nararee, Kotra and Deopur, 28 miles From Rawa onwards, numerous pieces of trap scattered over the surface, but not exceeding about 2 cubic feet in size In a river bed south-east of, and close to, Nararee, I observed large blocks of yellow limestone, it was however, very soft From about 2 miles short of, to $2\frac{1}{2}$ miles beyond, Kotra the road was hemmed in on either side by hills, bearing what appeared to me to be strong signs of volcanic action From Deopur saw the fort of Seeraghud It is built of a soft white free stone

2nd April.—To Chota Mhow, Mhow, Humla, Muzzul, Doon and Mandavie, 22 miles Near Muzzul noticed large blocks of soft red stone in small hillocks and in ravines, also small pieces of trap About 1 mile short of Doon is a river bed almost dry. The sides, which are high and steep, are chiefly composed of very large masses of irregular, contorted, indurated clay, containing cavities filled with crystals, there are several beds of this clay rock at different levels, each from 2 feet to 3 feet thick. It is compact, but hard only on the surface

At Doon I was told that there was no large hard stone near, but that at Gooneaseer, about 7 miles distant, stone somewhat harder than that at Hands' hill at Kurrachee was to be found, but it was in beds only 1 foot thick, though of considerable length and width.

3rd April.—Halted at Mandavie Examined the place and fort The stone used for these buildings is a rather soft limestone, some from Gooneaseer, and some from Lakaree, both above 10 miles distant from Mandavie. The fort walls are now being extended, and limestone for this purpose is brought by boats from a place about 6 miles along the Coast It is quarried below high water mark

4th April.—Examined the Protestant Cemetery The only monument in which the stone used is at all peculiar, or worthy of remark as of good quality, is one to the memory of Captain Remon, Bombay Engineers—1825 This is composed of green basalt, but the largest stone was only 1 foot 6 inches × 1 foot × 1 foot 3 inches, or $1\frac{7}{8}$ cubic foot. It had worn very well The monument was probably brought from Bombay.

5th April.—Major Shortt, Political Agent in Cutch, advised my examining a ravine near the village of Doonee, on the road to Bhooj, which

is mentioned in Grant's "Geology" as having perpendicular sides composed of compact columnar basalt of a greenish gray color, the columns being perfect polygons and of a very large size He informed me that he believed this to be the largest hard stone in Cutch, and recommended my going straight across Kattiawar to Chumardee near Bhownuggur, believing that thus only should I be at all likely to find what I required

I then proceeded by Assumbia, Tungwana, Chota Assumbia and Doonee, 20 miles towards Bhooj On the way, examined the ravine above-mentioned The largest stone which I could find was 6 feet high, 3 feet 6 inches wide, and 1 foot 9 inches thick, and probably weighed about $2\frac{2}{3}$ tons It was not sound, having several considerable cracks in it The columnar form was, however, striking, and the stone was the largest of the kind which I had then found

6th April.—To Dheysra, Megpoor and Bhooj—17 miles Left the hills which showed signs of volcanic action after about the first two miles.

7th April —Halted at Bhooj His Highness the Rao of Cutch, showed me fifteen specimens of stone proposed to be used in building a new palace about to be begun Two of these were basalt and most of them were of very good quality, but being procurable near Bhooj were too far from the sea for my purpose. One was a soft white limestone which, however, has stood very well in the carved work of some parts of the present palace, which I was informed were 150 years old It is very easily dressed when newly quarried I was told that within the influence of the sea-breeze this stone rapidly decays

8th April —To Mahdapoor, Bajooree, Kuckma, Tourwoee, Gunda, Warra and Keroee—22 miles. Crossed low hills showing signs of igneous action before reaching Gunda. The ground strewed on the Keroee side of the hills with pieces of trap, but nowhere saw it "*in situ*"—Rock, generally sandstone of a dark purple color, very large and hard, but apparently not wearing well

Visited the river near Keroee, mentioned by Captain Grant as affording a good specimen of columnar basalt, alternated with calcareous grit The basalt was very hard and covered a considerable area, but in size the blocks could not compare with those at Doonee.

9th April —To Vindiaroo, Deorio, Matak and Toonea—13 miles. Examined the fort at Toonea and stone in the neighbourhood, but found nothing at all approaching, either in quality or size, to what was required

In the evening left Toonea, where there is a good masonry jetty, and crossed the Gulf of Cutch, reaching Joona in Kattiwar on the 10th

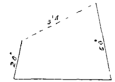
11th April.—Across flat marsh, apparently not long ago below high-water mark, 8 miles to Hurrianee, then 3 miles to Ballachorry on the sea shore There found large blocks of trap overlying soft red and white conglomerate, forming a cliff on which is built the Political Agent's Bungalow The largest block was 4 feet 6 inches × 3 feet 6 inches × 3 feet, or say it weighed $3\frac{3}{8}$ tons, the thickness of the bed of trap was about 12 feet About a quarter of a mile to the north is another cliff of similar formation The whole amount of trap, however, was evidently not sufficient to make it worth considering for the Breakwater, even if sufficiently large blocks could have been obtained

I therefore went on to Kujria, 10 miles across a salt swamp Then, passing near the village of Doon, 6 miles to Nowa Nugger At one mile short of that place inspected a small quarry, from which a hard gray stone was being worked for a Temple in Nowa Nugger. The largest pieces obtained were stated to be only 2 feet × 1 foot 6 inches × 10 inches, no powder, however, was used, and the stone was obtained from below the surface of a slight rise

On the 12th April I visited the Jam's works at Behree Bunder On the way saw several large (up to about 4 tons) blocks of blue and green trap on the surface of a slight rise They were very irregular in shape and full of cracks which, though then closed, would probably open in dressing The Jam's quarry is about 3 miles from Nowa Nugger, and 2 miles from the new jetty, where the stone is used It has been worked for three years to a depth of about 13 feet below the surface I was told that the stone extended to a further depth of 5 feet It appeared to be of very good quality, the green said to be harder than the gray Between the joints a thickness of from $\frac{1}{8}$ to $\frac{1}{4}$-inch of what appeared to be feldspar The largest stone which had been turned out was 2 feet 1 inch × 2 feet 9 inches × 2 feet deep, or probably of about $\frac{6}{7}$ ton weight. It was not, however, to the Jam's workmen, an object to get stones of large size, this being large enough for the work at Behree Bunder, and part of the road to that place being very bad

The largest stone which I could find in the quarry was in shape as shown on next page, only 3 feet 8 inches of its depth exposed I had

reason, however, to suppose that its average depth was about 5 feet $2\frac{1}{2}$ inches In this case the stone would have weighed about 8 tons The quarry had been begun at the place which appeared to me to promise better than any other near, and my examination of it and of the adjoining ground convinced me that, even if other objections, such as the stone being required for the Jam's works, could be overcome, very few stones, if any, of the size required could be obtained from this neighbourhood



The Jam's workmen used drills with $1\frac{1}{8}$-inch bits, the needle, and tolerably good powder, made in Nowa Nugger. I was informed that the rates given for labor at the quarry were—

1 Stone cutters—daily—Annas 10 to Rs 1
2 Carpenter—daily—Annas 12
3 Quarrymen and the best coolies— Annas 8
4 Cooly women—Annas 4

Major Keatinge, the Political Agent in Kattiawar, had advised my seeing Serryah Bunder, and, above all, Beyt From the former place however, I obtained a specimen of the stone procurable, which showed me that it would be quite unfit for the Breakwater, and to have gone there would probably have delayed me 3 or 4 days I had previously, in 1859, seen the cost at Beyt and Dwarka and from my recollection of the stone at those places, did not think it worth while for me to visit them again. I, therefore, proceded to Rajcote, in order to obtain further information from Major Keatinge, and on my way towards the Burdah hills

On the 13th, 21 miles to Humatee—crossed the river Oor, on the east bank of which were large blocks of trap, with conglomerate overlying

On 14th, 26 miles to Rajcote, obtained information from Major Keatinge about the places to be visited in the Burdah hills, on the coast between Porebunder and Gogo, and inland from the latter place

„ 16th —20 miles to Chibia and Chandlee

„ 17th —To Deyree, Kheyreree and Gool Doorajee, 24 miles.

„ 18th.—To Jarodhur, Wuddala and Diapha, 14 miles. Then by Kotra to Jodepoor, 8 miles. Noticed nothing worthy of remark with reference to the object of my journey between Hamattee and Jodeepoor.

On the 19th April by Jamwala and Veera to Bhanwar, 18 miles. At about 1 mile north of Veera observed large blocks of yellow limestone on the surface of a slight rise by roadside

20th —Went to Goomlee, examined the fine old temple, on by Mokana, skirting the bases of the Burdah hills, by Pasthur to Ranpoor, 13 miles In the afternoon ascended the Malek hill, found on going up, that for a considerable distance, *i e.*, about one-quarter of the way, the rock was limestone, very regularly stratified (much like that afterwards seen at Additiana). Above this, it was all hard, probably granitic. Descended by the way of the Chota Malek I saw on both of these hills large blocks of very hard stone, apparently syenite, of which a sample* acompanies

This stone would, I imagine, answer for the Breakwater. Many of the blocks are somewhat rounded, but they have, of course, been exposed for ages to great wear, and most of those, not at the summit, which I saw rolled down from a higher position, which would account for the fact of their angles not being sharp Some of the stones being rounded forms therefore no argument against the probability of their wearing well. Without seeing any attempt at quarrying made, it is difficult to judge of the cost at which suitable stone could be obtained from these or any of the Burdah hills, but I feel sure that stone of the requisite size could be obtained from them

On 21st —To Additiana, 8 miles, to see the quarries (which are about 2 miles north of the village), from which is obtained the stone well known by the name of "Porebunder " These are in a ridge of hills rising about 50 feet over the general level of the surrounding ground, and about parallel with the line of Burdah Hills on the north, the intervening valley being 1½ mile wide.

The stone is beautifully white, the stratification very regular, beds very flat, and the few joints square and true. It must be very easy to work, and with ordinary care, avoiding the use of powder, very fine large blocks might be got out In one of the quarries (Amand Patell's) I measured a stone, which I believe could have been got out without a single flaw, and found it to be 12 feet 6 inches long, 5 feet 6 inches deep and 6 feet 10 inches wide This probably weighed upwards of 33 tons. The stone

* The quartz and feldspar apparently in about equal proportions The hornblende in very small quantity

which was being quarried was, however, miserably small In fact, no means of lifting or removing heavy stones appeared to exist, and the road as far as Additiana, 2 miles towards Porebunder, from which port the stone is shipped to Bombay, could not be much worse

It is a great pity that such valuable building material should not be made the most of Though very soft and easily worked when lately quarried, it, I believe, hardens considerably on exposure.

No great height of face could be obtained, the ridge rising so slightly over the plain, but the length of ridge is considerable, extending about 3 miles towards the west and one mile towards the east Still, unless steps are shortly taken to work it properly, all that which is found above the surface of the plain, *i e*, which might be quarried most advantageously, will before long have disappeared, without a single fine block having been obtained from it

The stone would not, however, be nearly hard and durable enough for the Breakwater work. A small sample accompanies. The valley behind the quarries is full of large blocks, similar to those found generally at the base of the Burdah hills No water is obtainable at the quarries, it is brought from the village of Additiana, about 2 miles distant I was informed, however, that about one-third of the way up the Mor Chukna, the Burdah hill just north of the quarries, there was a spring which never failed

At the Additiana quarries the quarrymen, drillers and powdermen get 8 annas a day and their food These men also roughly hammer-dress the stones for carriage. Coolies for loading the stone on the carts are paid by piece work, and earn about $5\frac{1}{2}$ annas a day and their food.

On, 11 miles to Porebunder The road from Additiana is tolerably good and the ground favorable for a line of tramroad The creek at Porebunder would suit well for shipping stone from the Burdahs for Kurrachee in native craft The largest can pass, when loaded, over the bar at high water spring tides, and when light, at high water neaps. Vessels of such a size, however, as could pass over when loaded at high water daily, would probably answer the purpose. The bar, which is of rock, might, I should think, be much improved at slight cost.

Should it be decided to obtain the stone required for the Breakwater from the Burdah hills, the best plan would probably be to open a quarry on the south-west face of the More Chukna, to lay a line of light railroad

from it to Porebunder, and there to ship the stone for Kurrachee. It is possible that arrangements might be made to make the same railroad available for carrying limestone from the Additiana quarries to Porebunder, there to be shipped for Bombay, &c.

On 25th proceeded by steamer to Verawul. The coast until close to Verawul, where conglomerate cliffs rise to a considerable height, is very low, and I could observe no sign of its affording stone of the size required

26th —Went over the Harbor Works being carried out at Verawul for the Nawab of Joonaghur, by Mr Bahol Scott, Civil Engineer; also the quarry from which the stone for those works was being obtained. It is rather a soft limestone, very similar to that obtained from the Kurrachee Harbor Works quarries at Hands' hill

Went to the town of Puttan, examined the celebrated temple of Somnath Many of the stones of which it is built are very large One of them which I measured was 13 feet × $1\frac{1}{2}$ feet × $1\frac{1}{2}$ feet, another 9 feet × 2 feet 3 inches × 1 foot 4 inches Each of these probably weighed about 2 tons They were of a hard sort of pudding stone. I was unable to ascertain where this stone, or that of a dark red color with which the temple appears to have been paved, was obtained from The carving is excessively rich, and much of the stone appears, considering the great antiquity of the temple, to have worn very well.

Examined the fort of Puttan. In the afternoon, in a native boat 48 miles to Dieu, passing Vailun, Dieu Head, &c

28th.—Called on the Governor of Dieu, examined the fortifications, the cathedral, &c Afterwards proceeded by boat to Jafferabad, 24 miles.

The coast throughout this distance, as well as the latter part of that between Verawul and Dieu, is a succession of rather soft limestone cliffs, about 50 or 60 feet over sea level, craggy and broken away by the sea, in some places forming rocky islands

29th.—Examined the fort at Jafferabad The stone obtained from the cliffs above-mentioned would probably answer well for building in Bombay. It is flat bedded and can be obtained, if necessary, in very large blocks, and appears to be sufficiently durable for ordinary building purposes, though certainly not fit for the Manora Breakwater, and would be quarried very easily, and loaded direct into boats without any land carriage. Lime obtained from it is, I believe, taken in large quantities to Bombay.

In the afternoon went on in boat to Mhowa, 36 miles. Cliffs as between Dieu and Jafferabad.

On 30th to Goapnat, 25 miles.—Examined the cliffs there, which rise to about 80 feet over sea level. The base is of coarse, hard, conglomerate, over which lies sandstone, the whole being capped with apparrently the same limestone as that observed since leaving Verawul.

On 1st May reached Gogo, 37 miles, passing close to Perim island. The currents in the Gulf of Cambay are so strong that much delay is caused to boats, as it is quite impossible for them to work against the tide; the bottom too, in many places, is bad for anchoring. These drawbacks to the navigation of the Gulf would considerably increase the cost of stone procured for use at Kurrachee from any part of the Gulf east of Jafferabad.

On 2nd went to Bhownuggur, by land, 12 miles.—Visited the new jetty, &c., being made by the Thakoor near the town.

3rd.—Went by Seetra, Burtaiz, Kurtaiz, Bhojpara, Mhaisra, and Kanglee Villages, to Chumardee, 21 miles.

Examined the hills near the different quarries which had been opened, &c. Found the hills to be composed at base, of rather a soft sandstone which is used for ordinary building purposes in the village, also, I was informed, for road metal, and of a hard gray stone which appears to me to be syenitic, and of which a sample accompanies.

It appears to me to be very doubtful whether the quality of the hardest stone procurable at Chumardee (containing as it does so much of apparently very rotten feldspar) is such as to make it suitable for the breakwater. I was impressed in favor of it by information received as to the way in which it had worn in a building, said to be 600 or 700 years old, at Wulleh, 4 miles north of Chumardee. This was, however, I believe, in foundations only. I was on the other hand informed that it was not suitable for road metal, pulverising rapidly under heavy traffic.

There is undoubtedly sufficient stone in blocks of the size required on the Chumardee hills, and it would be quarried probably much more easily than that of the Burdah range. The hills at Chumardee are almost entirely composed of immense blocks, and there would be very little rubbish to clear away. The stone is used for road bridges in the neighbourhood.

At Bhownuggur

Stone cutters get	Rs	0	10	8	daily
Coolies	„	0	6	0	„
Women do	„	0	4	0	„
Boy	„	0	2	6	„
Drillers	„	0	10	0	„
Blacksmiths	„	25	0	0	monthly
Carpenters	„	30	0	0	„

Chumardee is distant by the creeks 22 miles from Bhownuggur Boats carrying about 1½ tons can go daily to within 3 miles of Chumardee, but at spring tides even those boats cannot more nearly approach that place

It is evident, therefore, that, at any rate, 6 miles of land carriage would be requisite. A line of railroad would have to be formed for that distance, the expense of which would be considerable, as the line would pass over a swamp, the material of which would be very bad for making, or for sustaining, a railway embankment, and, as the amount of water-way to be provided would be very great, screw piles would probably be adopted

It would be necessary to transfer the stone from such boats as could navigate the creeks into sea-going craft at a point somewhere near Bhownuggur. At Gogo there is not much water close in shore, moreover, it is much exposed To go to Bhownuggur to transfer would be out of the way, and in the Bhownuggur creek there is but little depth of water There is, however, a place in the main creek about 3 miles below the mouth of the Bhownuggur creek, at and up to which from the Gulf of Cambay there is a depth at low water ordinary spring tides of 30 feet, and here there would not be sufficient sea to interfere with the transhipment of the stone

I then went, by Kangleo to Shewr, 10 miles.—Examined the stone in the neighbourhood Saw fine masses of trap which might perhaps afford blocks of the size we require, but not favorably suited for quarrying, and far from water carriage, as compared with Chumardee. Noticed other hard stone of a dark blue color, in thin and very smooth beds. It would perhaps be a good material for roofing.

7th —Returned to Gogo.

8th —Crossed the Gulf of Cambay, and up the River Nerbudda to Broach, 48 miles

9th.—By Rail to Ahmedabad, 106 miles, to obtain information from the Executive Engineer about the stone at Chumardee, the results of use made of it by him, the cost of quarrying and dressing it, &c. Also information as to other possibly suitable stone in his districts.

11th.—To Baroda, 61 miles

12th —To Surat, 81 miles

15th —Visited the Bombay, Baroda & C I R, Company's quarry at Doongree, 37½ miles from Surat, into which a siding from the main line runs. Found that only about one-quarter of the Hill from which the stone was being quarried remained About a quarter of a mile further from the railroad are some other small hills of similar appearance, but I was told that there was no good stone near, except that of the hill in which the quarry was It appeared to be trap of good quality It is 8 miles from Dandee Bunder on the sea coast I saw some dressed stones which I was told had been obtained for Government with great difficulty. They were each 4 feet 6 inches × 2 feet × 1 foot 6 inches, or, say about 1 ton in weight This quarry did not lead me to suppose that there would be the slightest prospect of obtaining such blocks as those required for the Manora Breakwater near Doongree

16th.—Went to the Palmeera hill, examined stone composing it, as also that in the bed of the Par river beyond, some of the latter columnar basalt apparently, neither the least likely to afford 10 ton blocks, or any thing approaching to such a size

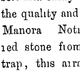
To Pardee railway station, 8 miles from Bulsar Went on a lorry to the Railway Company's Quarry at Bhugwara There appeared to be a much greater quantity of stone there than at Doongree, and the quality of the trap (dark blue and gray with large crystals of quartz,) apparently good. It was, however, evident that no such weight as 10 tons in one block could be obtained On by lorry to Damaun road station, and then on foot to Damaun, 8 miles.

17th.—Made enquiries about the stone obtainable near Damaun It seems that, at 2 miles off, dark blue, close grained trap is obtainable of considerable length and width, but not more than 1 foot thick. This, of course, rendered it useless for the Kurrachee Harbor Works

18th —By train to Sunjan station, and thence by lorry 4 miles to Kookranee quarry. It is situated about one mile east of the railway line and is not connected with it by a siding Examined stone there, a dark colored trap It appeared to be of very good quality, but not nearly large enough for the Breakwater. On, by lorry again, to Golwud 6 miles, and then to Dannoo road station. Thence by train to Bassein road station, 45 miles.

19th.—On lorry back to the Railway Company's quarry at Neela

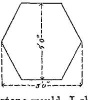
Doongree, about 3 miles, apparently laterite, of several bright colors, soft and easily worked. The quarry has a fine face, about 50 feet high, but the quality and size of the stone render it quite out of the case for use at Manora. Noticed the station buildings at Veraur which are built of red stone from Neela Doongree, with quoins, &c., of green and gray trap; this arrangement had a very good effect. Saw a Dhurumsala which was being built near the station by the Public Works Department, of trap quarried near, but I could not discover that there was any likelihood of getting really large stone from any place in the neighbourhood. Returned on lorry to Bassein road station. Then on lorry about 2 miles to the Bassein creek bridges, and by boat about 4 miles to Daravee, on the south, or left, bank, beyond Bassein. Examined the quarry which had been worked for the Bombay, Baroda and Central India Railway Company. Found there very fine columnar basalt. The largest blocks, which were lying on the beach ready to be shipped, were as follows:—



One of section as in figure—length 4 feet 8 inches, a few slight shakes on the outside, but otherwise quite sound.

Another of section as in margin and 6 feet 3 inches long. Quite sound, of a gray color, but on the outside yellow. The longest stone lying ready for shipment was 13 feet long.

The heaviest stone seen by me was about 100 yards east of the place where the columnar stone had been quarried. It was "*in situ*." It was 11 feet high and 5 feet wide from the extremes of the polygon, and I could see back 2 feet 6 inches, which was probably half its thickness, or in plan it was probably somewhat like the annexed figure, and perhaps weighed about 13 tons. I doubt, however, whether a stone weighing 10 tons of the shape required for the Manora Breakwater could have been obtained from it.

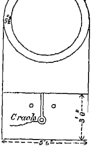


The face of the quarry exposed columnar stones without break, 15 to 20 feet long, and I have no doubt that they might be obtained considerably longer. The joints, although not quite out of winding, are very smooth, and from the great lengths procurable, this stone would, I should think, for some purposes be very valuable.

There are great facilities for shipping the stone, as native craft of upwards of 100 tons burden can (so I was informed) come so close up to the quarry as to allow of the blocks being loaded by cranes direct into them The face of the quarry is high, and the stone, of which there is a very large quantity at Daravee, can be quarried very easily and cheaply, as, from its formation, it comes away most readily, and there is very little small stuff requiring removal. Still a very large quantity would have to be quarried in order to obtain the blocks necessary for the Breakwater, even if, from the peculiar shape of the stones, such could be procured at all Moreover I saw the pitching of a slope near the Bassein railway bridge, for which this stone had been used, and it had already begun to peel off. This action I also noticed in the stone at and near the quarry, and likewise in some of the old buildings at Bassein, but to a much greater extent, for which the Daravee columner basalt had been used I do not, therefore, think that the quality of the stone would be such as to warrant its adoption for the Manora Breakwater, even if doubt as to obtaining it of the required size did not exist. A small specimen of the Daravee stone accompanies

20th May To the Bombay, Baroda and Central India Railway Company's quarry at Andhera Trap not particularly large. The stone obtained from below the surface of the ground. Went further on to see a place from which limestone was quarried—soft and of little value.

To Bandora. Saw the Company's quarry immediately in front of the Railway station, and adjoining the line Trap quarried from pits.



After rain, pits abandoned and new ones opened Some large blocks however obtained 5 feet × 4 feet × 1 foot 8 inches, or about $2\frac{1}{3}$ tons each. The Foreman, who apparently knew the surrounding country well, informed me that he considered the quarry the best anywhere in the neighbourhood.

Near an old Portuguese Church, on the west side of the railway, saw a large stone vessel, *see Fig* It probably was obtained from a block weighing about $6\frac{1}{2}$ or 7 tons. It was of a coarse hard sandstone, and I was informed was brought from Coorla on the G. I P. Railway Line.

In evening to Bombay.

25th.—Left for Kurrachee, where I arrived on the 29th May

No. CCXXVIII.

PILE ENGINE FOR SEA WORKS.

To the Editor.

SIR,—In one of your issues, which is not by me just now, there was a description of a pile engine, stated to be suitable for river or sea works, I had one of those engines constructed for the purpose of driving the piles for a wooden pier on the coast, but it was not found to answer, and I do not think it is possible to use it where there is a heavy ground swell, or indeed a strong current of any sort

I forward a tracing and an estimate of a Flat, bearing a Pile Engine, which I substituted for the previous arrangements, and I found work to proceed much more satisfactorily and expeditiously, and I trust it may be useful to any of your readers before they (as I did) lose time and money by going to work with an engine suitable, I believe, only to the dry beds of the Deccan streams. The flat and engine is in common use in Bombay Harbor at the Elphinstone Land and Press Reclamation Works.

Estimate framed by CAPTAIN J R. MAUNSELL, R E, *Executive Engineer, Northern Konkan, of the probable cost of making a Pile Engine and Flat*

General Description.

The engine for driving the piles is supported on a flat, the upper surface of which measures 31 feet × 21 feet, and the bottom 29 feet × 19

feet, and is 4 feet 9 inches in height, thus showing the sides sloping 2 feet $44\frac{1}{2}$ inches vertical to 1 foot horizontal, the flat is sufficiently large to accommodate the required number of work-people employed in driving the piles

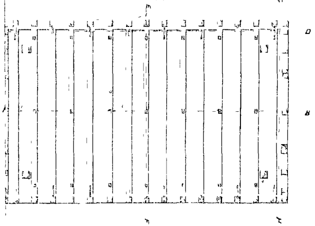
The pile engine is 29 feet in height, and supported upon strong bed plates firmly fixed to the flat, and kept in position by struts and braces The ram, which weighs 7 cwt, has ears which slide up and down the groove between the uprights, and is kept close to their face by a fish-plate which is keyed to the ears, the uprights are protected by flat bar ($2\frac{1}{2} \times \frac{3}{8}$-inches) iron to prevent the ram or fish-plate damaging them The ram is raised by a powerful crab winch and chain, the chain passes over a large iron pulley, the axle-boxes of which are fixed on to the top plate To one end of the chain is secured, by a screw bolt and nut, the lifting dog or clips, these require to be taken off each time a pile is to be placed in position, as the piles are raised by this end of the chain being passed round them once and fastened by two half hitches, it is then raised perpendicular by the men at the crab, and lashed to the uprights, and the flat is then brought into the position required, the lashings on them eased, and the pile gradually lowered until it rests on the ground, when the chain is taken off and again secured to the lifting dog or clips During the time a pile is being raised, the ram rests upon a strong iron bolt which passes through the upright near the top plates

Construction.—The whole of the wood to be of well seasoned teak, framing to be mortised and tenoned together, and secured by angle-plates with screw bolts and nuts. Tender around flat to be protected by bar iron 3 inches $\times$ $\frac{1}{2}$-inch.

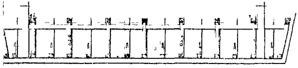
Abstract Estimate for Flat

		RS.
655	Cubic feet teak wood, at Rs 5 per cubic foot, ...	3,275
4	Anchors, at Rs 50 each, ...	200
4	Cwt Manilla rope, at Rs 40 per cwt, ...	160
2	Boat hooks, at Rs 15 each, ...	30
4	Cwt. angle-plates with bolts, nuts, &c, at Rs. 27 per cwt,	108
		3,773
	Contingencies at 5 per cent,.. ..	188
		3,961

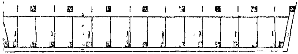
PLAN OF LOWER PART OF FLAT



SECT LONGITUDINAL SECTION ON AB



SECTION ON CD



Abstract Estimate for Pile Engine.

		RS.
132	Cubic feet teak wood, at Rs. 5 per cubic foot, ...	660
1	Crab winch, at Rs. 150 each, ...	150
100	Running feet (2 cwt.) iron chain $\frac{1}{2}$, at Rs. 20 per cwt., ..	40
1	Cast-iron ram, 7 cwt, at Rs 16 per cwt, ...	112
1	Iron bolts and chain, at Rs 5, ...	5
1	Lifting dog, at Rs. 25,..	25
2	Cwt angle plates, bolts, &c, at Rs 27 per cwt, ...	54
		1,046
	Contingencies at 5 per cent, ..	52
		1,098

Recapitulation

	RS
Pile engine, ...	1,098
Flat, ...	3,961
Total Rupees, ...	5,059

BOMBAY,
30th January, 1869.

"REWAS."

No. CCXXIX.

TANK IRRIGATION IN AJMERE AND MHAIRWARA

Report by LIEUT. F. HOME, R.E., *Exec. Engineer.*

To Superintending Engineer, 2nd Circle, Irrigation Works, N. W. Provinces, dated 3rd August, 1868.

SIR,—I have the honor to report that, in accordance with instructions received from the Chief Engineer, I left the Bhurtpore District on the 26th September, 1867, and after inspecting some of the principal tanks of Ajmere and Mhairwara, returned on the 2nd November, 1867; the journey there and back took up a considerable portion of the time, the duration of my actual stay in the two districts being 26 days.

Proceeding from Ajmere, I met the Deputy Commissioner at Nya Nuggur, and marched through Mhairwara in a south-westerly direction towards Todgurh. In this way I passed through the tract in which the principal tanks are situated, and was enabled to select some of the larger ones for measurement. I had also an opportunity of inspecting the terrace cultivation, and one of the Burar wells in the vicinity of Todgurh.

The country through which I passed changes from undulating near Nya Nuggur to hilly in the neighbourhood of Kabra, from Kabra to Burakhun the hills increase in number, and cultivation is restricted to the valleys—there being scarcely any soil on the hill sides. There are no plains in this portion, and cultivation is almost, if not entirely, dependent on artificial irrigation. Beyond Burakun there is a sudden rise of about 500 feet to the plateau on which Todgurh is situated, the surface of this plateau is, for the most part, covered with a fair coating of soil, and in many of the valleys, by which it is intersected, cultivation is carried on by

means of artificial terraces, I saw these in great perfection at Dansurean, on the road from Buiakhun to Todgurh.

Selecting four of the larger tanks—viz, Loosanee, Dewatun, Kabra, and "Kalee Kankur"—I took, on my way back, soundings of their depths, and made enquiries about their construction, and about the crops irrigated from them. On my return to "Nya Nuggur," I extracted all the information I could get from the Settlement records, and marched to Nusseerabad in the Ajmere District.

In the neighbourhood of Nusseerabad, and, indeed, throughout the Ajmere District, the hills are more scattered than in Mhairwara. The surface of the country between the hills is undulating, and rock crops out in many places through the upper stratum of soil. The commoner Khureef crops ripen in a fair rainy season, but Indian corn and the Rubbee crops do not in ordinary years thrive without irrigation. I selected for measurement two large tanks near Nusseerabad—viz, "Duiathoo" and "Nearan."

The areas of the tanks when full are all given in Colonel Dixon's book, but no mention is made of their cubical contents, this latter information it was absolutely necessary to obtain, since it forms the basis of all calculations on the subject of tank irrigation, and soundings were accordingly taken from a boat at equal distances on lines as nearly as possible parallel to and at equal distances from each other, whence the mean depth of the whole tank was obtained, and the surface area being known, the cubical contents were determined.

The following tanks were measured, viz.:—

1.—Loosanee	...	Mhairwara
2.—Dewatun	...	Mhairwara
3.—Kabra	...	Mhairwara
4.—Kalee Kankur	...	Mhairwara
5.—Duiathoo	...	Ajmere
6.—Nearan	...	Ajmere

and twenty-two tanks and weirs were inspected in the two districts. The results obtained are shown in Appendix B., No. IV.

It may here be observed that the irrigation works in Ajmere and Mhairwara are not merely preventives against famine in years of drought, but are, as a rule, absolutely necessary to the production of crops. The undulating nature of the country causes the rain-fall to flow off the surface of

the country very rapidly, and the beneficial effects of a heavy fall of rain last but a very short time This evil again is aggravated by the spasmodic nature of the rainy seasons, the greater portion of the rain frequently falling within a short time, instead of being evenly distributed over the months during which wet weather may be expected

The tanks are not intended for perennial irrigation, but were designed with a view to securing both the Khureef and Rubbee crops This object they fulfil, as far as I could judge, exceedingly well The most important crops raised by them are in the Khureef, Indian corn; and in the Rubbee, barley and gram Wheat is grown to a small extent during the Rubbee, and the commoner crops, such as "bajra" and "jowar," are largely sown during the Khureef, small quantities of rice are also met with in the immediate rear of the embankments.

The Khureef is sown after the first fall of rain, and the whole of it generally receives a watering at the end of September, or the beginning of October, which brings it to maturity, if the season is unusually dry, it requires two waterings, the crop is then cut, and the ground, retaining the moisture from the last watering of the Khureef, is immediately ploughed up for barley or gram The Rubbee crops receive two or three waterings from the tank according to the quantity of water available; any deficiency being made up by irrigation from wells, which are quickly and cheaply made,—the water being kept close to the surface by percolation from the tank

The success of the tanks from an agricultural point of view is undoubted, and the financial results, as shown by Colonel Dixon in pages 137 and 205 of his book, are equally satisfactory.

Districts	Expenditure on tanks	Increase of revenue due to tanks
	RS.	RS
Mhairwara, ...	2,41,112	6,41,234
Ajmere, ...	3,76,451	3,17,771
Total Rs., ..	6,17,563	9,59,005
	Net gain, Rs., ..	3,41,442

Table IV., Appendix B, also shows that of the six tanks examined by me, all except one (Durathoo) are, after paying all expenses, giving a return for the money expended on their construction, and that the net income of the whole six is nearly 5 per cent on the total capital.

This favorable result is undoubtedly due in part to the cheapness of original construction. The following are averages of the rates given by Colonel Dixon in his book:—

Description of work	Rates					
	Mhairwara			Ajmere		
	Rs	A	P	Rs	A	P
Masonry set in lime, per 100 cubic feet, ..	3	13	3	4	12	11
Do do mud, ditto, ...	2	6	3	2	7	0
Earthwork in embankment, per 1,000 cubic feet,	2	8	0	3	0	8

The rates now obtaining for masonry are double those above quoted, and the earthwork rates have also risen, though not in the same proportion.

The maintenance and repairs of the tanks are carried on by the District Officers, each Tehseeldar having immediate charge of the tanks in his pergunnah, the only professional supervision that they receive is from Mr. Supervisor Barry, who receives a salary of Rs 150 per mensem, and who has, I understand, the charge of the district roads as well. This officer directs the nature of the repairs to be undertaken by the Tehseeldars, and draws up designs and estimates for new works.

The funds for repairs to tanks are, according to the description given in page 73 of Colonel Dixon's Settlement Report, derived as follows:—

"The original cost of the tanks, up to the date that the Settlement commenced, is added to the net revenue as settled by Colonel Dixon, and a cess of one per cent is taken on the whole."

This, according to information obtained from the Deputy Commissioner's office, yields per annum—

For Ajmere District, .. Rs 5,125.
For Mhairwara do., .. „ 3,345.

It will thus be seen that the maintenance of the works is carried on in the most economical manner possible, and that this is done without sacrificing efficiency, is proved by the good order in which I found the embankments that I inspected, in many of them, the old front wall of dry stone masonry plastered on the outside had been replaced with one of masonry in lime, and in others leakage had been stopped by covering the face of the front wall with a slope of earth, the cost of all this work is defrayed from the yearly grants above-mentioned. I consider that the condition of the works reflects great credit on the officers who have the management of them

The averages of columns 4 and 7, Table IV, Appendix B, may perhaps prove useful in drawing up projects for new tanks Column 4 shows that each acre requires 177,261 cubic feet to irrigate it, now, irrigation is only carried on from these tanks for about six months in the year, hence double that amount would at first seem to be required to irrigate one acre for a whole year. This, however, is not the case, for the irrigated land is nearly always double-cropped, as explained above, and consequently the volume above-mentioned would actually suffice to irrigate one acre for one year, that is to say, the land would require a total depth of 4 07 feet of water during the whole year, or one cubic foot of water per second from the tank would irrigate 178 acres in a year. The gross revenue has been taken as the basis of the calculations for column 7, in order that they may not be affected by the cost of original construction, which varies greatly with convenience of site and facility in obtaining materials.

Since completing my tour of inspection in Ajmere and Mhairwara, I have had the opportunity of visiting some of the tanks in the Jhansie District, the features of the country are much the same in both districts, but in Jhansie the cultivators did not appear to be equally eager for water, this may be due in part to the larger rain-fall in Jhansie, which would naturally render them more independent of artificial irrigation The record of rain-fall in Ajmere and Mhairwara is I am sorry to say, rather incomplete, but I could not get any more information on the subject. I have only the average rain-fall of the Jhansie District for the years 1865-66 and 1866-67. The following table shows that for those years the comparison is greatly in favor of Jhansie :—

Year	Average Rain-fall in inches		
	Ajmere	Mhairwara	Jhansie
1865-66, ...	16 76	18 17	31 46
1866-67, .	21 51	19 48	34 27

APPENDIX A

The "Loosanee" Tank.

The embankment forming this tank, as shown in the accompanying sketch, consists of three parts Commencing from the left we have—

An embankment of an aggregate length of 853 feet, of which 580 feet is an earthen embankment of small section, and the remainder forms two masonry escape weirs, whose respective lengths are 202 5 feet and 70 5 feet There is one outlet for irrigation in this portion.

Between this and the main embankment is a low range of rock about 1,000 feet long

The main embankment is 575 feet long, and is thrown across the supplying nulla It consists of a front retaining wall of masonry in lime, an earthen embankment with a slope to the rear, and a rear retaining wall of dry stone to support the toe of the earthen slope The front wall has a maximum width at foundations of 29 feet, decreasing through a height of 24 feet to a top width of 3·5 feet, the maximum depth of foundations is 20 feet

The earthen portion has a top width of 75 feet, with a rear slope of about 2 to 1.

The rear retaining wall averages about 3 feet in thickness.

There are two outlets for irrigation in this portion—viz, one cut through the rock to the left of the embankment, and the other piercing the left flank of the embankment itself.

Both flanks of the embankment rest upon solid rock.

Between this and the next portion is a small rock about 200 feet long.

The total length of the 3rd or right portion is 190 feet; it consists of an escape weir 107 feet long with two side walls raised eight (8) inches

above the sill of the weir, the lengths of these walls are respectively 29 75 feet and 53 25 feet The whole is built of masonry in lime, and an irrigation outlet passes under the centre of the weir. The sills of all the weirs are 4 feet 6 inches below the top of the main embankment

One of the weirs in the 1st (left) portion was breached during the rains of 1867 in a length of 38 feet, and the whole of that piece requires strengthening,—the masonry in the weirs being a very inferior description, and the section of the earthwork too small.

Area of tank = 600 Mhaurwara beegahs of 1,764 square yards, or 15,876 square feet each.

= 9,525,600 square feet.

Cubical contents = 76,984,185 cubic feet.

THE "DEWATUN" TANK.

The embankment forming the Dewatun Tank is constructed across a Nuddee which rises in the hills near "Saroth," and, after supplying in the order named the "Dewatun," "Kabra" and "Kalee Kankur" tanks, flows past the town of "Nya Nuggur."

The work consists of a front wall of masonry in lime 1,333 feet long, raised to a height of 3 5 feet above H. W. M of tank, having a width at foundations varying from 4 5 feet to 10 5 feet and at top from 3 to 5 feet, its maximum height is 16 feet, the depth of the foundations ranges from 6 to 9 feet at the flanks, and from 20 to 25 feet in the bed of the Nuddee.

To the rear of the masonry wall is an earthen embankment having a top width of 10 feet and a rear slope of 1 to 1

On the left flank is an escape weir having a length of 118 feet; its foundations rest on rock, and its sill is 3 5 feet below the top of the embankment.

There are altogether five irrigation outlets, viz :—

On the left flank	2
On the right flank	3

Of the former, one is shown in the accompanying sketch to the left of the escape weir, and the other (which is not in use) to the right of it. Of those on the right flank, the first is close to the lowest point of the

tank and drains all the water in it, the second is on a slightly higher level, and the third is at the right extremity of the embankment.

There is an extensive spread of ground to the rear of the tank, and the whole of the water is used for irrigation

Area of tank = 400 Mharwara beegahs of 1,764 square yards, or 15,876 square feet.

= 6,350,400 square feet

Cubical contents = 40,036,224 cubic feet

THE "KABRA" TANK.

The length of the embankment forming the Kabra tank is 620 feet.

Its construction is similar to that of the Loosanee tank embankment, already described

The front retaining wall is of masonry in lime, its maximum width at foundations is 27 feet, decreasing with a batten on both sides through a height of 20 feet to 10 feet at the top The depth of the foundations is 9 feet.

The earthen portion has to top width of 24 feet and a rear slope of 2 to 1.

The rear retaining wall is of dry stone masonry plastered on the outside faces, its height is five feet and average thickness two feet.

There are two outlets for irrigation—viz, one underneath the escape weir on the right flank, and the other cut through the rock on left flank.

They are both on the same level, and drain the water to a depth of 8·25 feet below sill of weir.

After the outlets cease to work, the water is raised by means of Persian wheels and leather buckets (*bhokas*)

The tank never dries up completely owing to the small area of land in its rear, and to the greater economy of water caused by its having to be lifted.

There is one escape weir on the right flank, whose sill is 30 feet long, and 5·25 feet below the top of masonry wall of embankment.

Area of tank = 500 Mhairwara beeghas of 1,764 square yards, or 15,876 square feet.

= 7,938,000 square feet

Cubical contents of whole tank = 57,693,384 cubic feet.

THE "KALEE KANKUR" TANK.

In construction it is somewhat similar to that of the Dewatun tank, differing only in the greater length of its embankment and escape weirs

Its length is divided as follows —

	Left		*Right*		
Embankments, . .	1,820	+	500	=	2,320 feet
Escapes, .. .	882	+	167	=	1,019 ,,
			Total length	=	3,369 ,,

This embankment is the finest that I saw in Mhairwara

The front retaining wall of masonry in lime has, in the middle for a length of 600 feet, a thickness at foundations of 42 feet, while in the other portions it is 9 feet thick, the thickness at top varies from 6 feet in the middle to 2 5 and 3 feet on the flanks the depth of the foundations throughout ranges from 4 5 to 6 feet, and the maximum height above the ground is 28 feet.

The earthen slope has a top width of 30 feet, and a rear-slope of 2 to 1.

The sills of the escape weirs are 4 feet below the top of the masonry wall.

There are in all 10 outlets for irrigation—viz, in the main embankment six (6), and in the escape weir on the left flank four (4).

The area of the tank = 500 Mhairwara beegahs of 1,764 square yards, or 15,876 square feet.

= 7,938,000 square feet.

Cubical contents, = 55,932,220 ,,

THE "DURATHOO" TANK.

The Durathoo tank is situated close to the Cantonment of Nusseerabad

It consists of two portions, the respective lengths of which are :—

	Embankment	Escape weirs	Total
Left flank, ...	1,331	320 + 125 = 445	1,776
Right flank, ...	1,215	115	1,330
Total feet,	2,546	560	3,106

Left Flank —The front retaining wall of masonry in lime is 10 feet thick at foundations, decreasing to steps in front to 4 feet at top, its maximum height from the ground is 22 5 feet, and depth of foundations 12 feet The earthen embankment has a top width of 13 feet, and a slope of $1\frac{1}{2}$ to 1 to the rear, the slope is supported at its toe by a retaining wall of dry stone 4 feet in height, its thickness is 2 5 feet in foundations, and 2 feet in superstructure

There are two escape weirs in this portion—viz., one on the left 320 feet long, and the other on the right 125 feet long. Their sills are 5 feet below the top of front wall

Right Flank.—This portion crosses the supplying nullah and was built first The front retaining wall of masonry in lime has a maximum height of 30 feet, and 15 feet is the maximum depth of its foundations its thickness at foundations is 15 feet, and at top 7·5 feet The earthen embankment is 20 feet broad at top, and has a rear slope of 2 to 1 The wall of dry stone masonry which retains the toe of the slope is 6 feet high, and has a thickness of 3 5 feet in foundation and of 2 5 feet in superstructure

There is one escape weir in this portion, its length is 115 feet, and its sill is 6 feet below the top of the front retaining wall

There are five outlets for irrigation in the whole tank—viz, two in the left and three in the right flank

About 16 years ago a breach, 225 feet long, occurred in the left flank close to the weir at its right extremity, it was repaired, and the portion breached was strengthened with counterforts

The tank has not filled since the year 1863, notwithstanding that the basin has silted up considerably. This does not appear to be due to any shortcoming in the rain-fall, but rather to the construction of small tanks in the villages situated above the tank

Area of tank = 1,000 Ajmere beegahs of 1,936 square yards or 17,424 square feet.

= 17,424,000 square feet.

Cubical contents of whole tank } = 127,836,403 cubic feet.

THE "NEARAN" TANK.

Plan and section of the embankment forming the Nearan tank are

appended its total length is 1,951 feet, which is distributed as follows, viz —

			feet
Embankment,	.	..	1,413
Escape weir,	. ...	..	538
		Total,	1,951

The embankment consists of a front retaining wall of masonry in lime, strengthened with counterforts, an earthen embankment, and a rear retaining wall of dry stone plastered with lime on the outside

Referring to the section on A, B, it will be seen that the thickness of the front wall at foundations is 17 feet, and that this thickness is continued up to a height of 12 feet 8 inches above the bed of the tank, from this point it gradually decreases, the top width being 4 feet

The earthen embankment has a top width of 15 feet, behind this it slopes with a gradient of about $2\frac{1}{2}$ to 1 through a height of 13 feet, next comes a berm 17 feet wide, supported by the rear retaining wall, which is 3 feet thick at foundations and 15 feet thick at top.

The total height of the embankment above the ground is 25 feet

The escape weir is situated on the right flank of the embankment its sill is 625 feet below the top of the front wall, and the length of its sill is 490 feet. The right flank of the weir abuts upon solid rock, as does also the left flank of the embankment

The weir is built of solid masonry in lime, and is of the section shown in the drawing, the tail apron was added some years after the work had been completed

This embankment closes two drainages, and is a very fine piece of work.

There are six outlets for irrigation from the tank—viz, one cut through the rock on the left of embankment (which being on a very high level is not in use), two in the embankment itself (of which that on the left flank only is used), and three under the escape weir—all of which are in use.

Area of tank = 800 Ajmere beegahs, of 1,936 square yards, or 17,424 square feet.

= 13,939,200 square feet.

Cubical contents of whole tank } = 106,239,286 cubic feet.

*

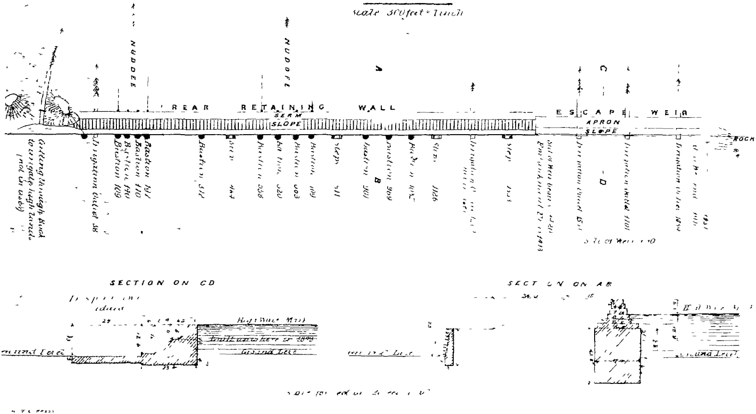
Plans and sections of the Durathoo, Kalee Kankur, and Kabra Tanks are given in Col. Dixon's Work.

PLATE XX

TANK IRRIGATION IN AJMERE.

PLAN OF NEARUM TANK EMBANKMENT

scale 300 feet = 1 inch



APPENDIX B, No. I

Revenue Statement of Irrigation Works, Mhairwara and Ajmere, from period of first construction to the close of 1866-67

Name of tank.	Constructed in	Capital.	Charges: Interest at 5 per cent	Charges: Maintenance and repairs	Charges: Total	Income (Increase of land Revenue)	Balance of: Charges	Balance of: Income	Remarks
		RS.	RS.	RS	RS	RS	RS.	RS.	
1 Loosanee, .. .	1840-41	11,125	15,012	2,484	17,496	34,173	.	16,677	There is no record of the amount spent on repairs to each tank during each year, but the *average annual* expenditure on repairs to *all* the tanks in Mhairwara, taken for the last eight years, is Rs 4,056 The total area covered by the beds of tanks is 26,549 beegahs, hence the rate for 100 beegahs is Rs. 15 3 per annum, and this has been assumed as a constant for all the tanks The area covered seems a fairer basis to start from than the original cost as the larger and more expensive embankments were built throughout with lime, and consequently require less repair than the smaller ones, which were as a rule only faced with lime plaster —in fact a great portion of the expenditure on repairs of late years has been incurred in replacing the dry stone walls of the smaller embankments with walls set in lime
2 Dewatun, . ..	1842 43	13,302	16,625	1,550	18,175	33,114	.	14,939	
3 Kabra, .	1839 40	7,673	10,752	2,156	12,908	25,588		12,680	
4 Kalee Kankur,	1844 45	24,790	28,497	1,771	30,268	29,930	338	..	
5 Durathoo, ...	1846 47	31,712	33,306	3,612	36,918	26,771	10,147	..	
6 Nearan, .	1849 50	32,076	28,872	2,484	31,356	1,01,826	.	70,470	
							10,485	1,14,766	
Total, ..	..	1,20,678	1,33,064	14,057	1,47,121	2,51,402	..	1,04,281	

APPENDIX B, No II

MHAIRWARA IRRIGATION WORKS

Statement showing Revenue and Irrigated Area

Name of tank	Village	When founded	Annual Revenue: Before tank was made	Annual Revenue: A. From period of construction to 1848-49	Annual Revenue: B. After settlement	Area irrigated	Increase in Annual Revenue: Period A	Increase in Annual Revenue: Period B
			RS	RS	RS	ACRES	RS	RS
Loosanee	Loosanee, ...	1837	100	343	550	66 70		
	Khera Dantu,	1837	80	259	240	29 16	977	1,410
	Rawut Mal, .	1840	.	555	800	96 23		
Dewatun	Dewasun, ..	1826	125	141	410	60 22		
	Bambeepoora, ...	1842	...	153	270	55·26		
	Kishunpoora, .	1842	..	124	325	45 38		
	Kulata Khera,	1842		109	210	45 29	687	1,580
	Baieanuggur,	1842		169	320	60 65		
	Jugpoora, .	1842	...	71	115	35 47		
	Khanpoora, ...	1844	...	45	55	0 73		
Kabra	Kabra, ..	1823	473	1,014	1,594	57 96	541	1,121
Kalee Kankur	Kalee Kankur, ..	1844	...	190	390	76 31		
	Kishunpoora,	1844		146	300	84 42		
	Himmutpoora, ...	1844	..	107	175	30 96	802	1,440
	Ummurpoora, ...	1844	...	151	225	64 86		
	Ghazeepoora, ...	1844	...	67	60	17 80		
	Lalpoora, ...	1838	70	211	360	64 97		
	Total, ..	...	848	3,855	6,399	892 37	3,007	5,551

APPENDIX B. No III

AJMERE IRRIGATION WORKS.

Statement showing Revenue and Irrigated Area—Durathoo Tank

Village	Revenue							Area irrigated
	Average before tank was made	1846 47	1847-48	1848-49	1849 50	1850-51	1851-52 to 1866 67	
	RS	RS.	RS	RS	RS	RS	RS	ACRES
Durathoo, ...	4,243	4,565	4,386	5,419	4,921	5,223	5,009	403 68
Ratha Khera, ...	.		..	.	.	..	551	44 46
Miscellaneous, ...						.	150	
Total, ...	4,243	4,565	4,386	5,419	4,921	5,223	5,710	448 14
Balance due to tank, .		322	143	1,176	678	980	1,467	.

Nearan Tank

Village.	Revenue																			Irrigated area in acres.
	Average up to 1818-40	1849-50	1850-51	1851-52	1852-53	1853 54	1854-55.	1855-56	1856 57	1857-58	1858-59	1859 60	1860-61	1861-62	1862-63	1863 64	1864-65	1865-66	1866-67	
	RS	RS.	RS.	RS	RS	RS	RS	RS	RS	RS.	RS	RS.	RS.	RS	RS	RS	RS.	RS.	RS.	
Nearan,	561	2,300	4,576	4,493	6,013	6,750	6,900	8,000	7,000	7,230	7,000	7,000	6,006	5,502	7,006	6,000	6,000	6,000	6 000	
Miscellaneous,	.	..		.		62	207	155	219	208	132	161	94	101	162	159	142	184	168	
Total, .	561	2,300	4,576	4,493	6,013	6,812	7,107	8,155	7,219	7,438	7,132	7,161	6,100	5,603	7,162	6,159	6,142	6,184	6,168	913 94
Due to tank,		1,739	4,015	3,932	5,452	6,251	6,546	7,594	6,658	6,877	6,571	6,600	5,539	5,042	6,601	5,598	5,581	5,623	5,607	

APPENDIX B., No IV.

Comparative Statement showing results obtained from Examination of Tanks in Mhairwara and Ajmere

Name of tank.	1	2	3	4	5	6	7	8	9		10		11
	Superficial area of tank when full	Cubic contents of tank when full	Area irrigated from tank	Cubic feet required to irrigate one acre	Gross revenue due to tank	Gross revenue per acre irrigated	Gross value of one million cubic feet of water in tank	Capital	1866-67 *Balance of*		1866-67 *Net percentage on capital*		Mean depth of whole tank
									Income	Charges.	Gain	Loss	
	S F	C F	Acres		RS	RS	RS	RS.					
1 Loosanee, ..	9,525,600	7,69,84,185	192 09	4,00,771*	1,410	7 34*	18 31	11,125	762		6 85	.	8 08182
2 Dewatun, ..	6,350,400	4,00,36,224	303 00	1,32,133	1,560	5 21	39 50	13,302	853	..	6 41	.	6 30452
3 Kabra, ..	7,938,000	5,76,93,384	57 96	9,95,400*	1,121	19 33*	19 43	7,673	660	..	8 60		
4 Kalee Kankur, ..	7,938,000	5,59,32 220	339 32	1,75,409	1,440	14 24	25 72	24,790	124	..	0 50		7 268
5. Durathoo, .	17,424,000	12,78,36,403	448 14	2,85,260	1,467	3 27	13 76	31,712		291	.	0 92	7 3368
6 Nearan, ..	13,939,200	10,62,39,286	913 94	1,16,243	5,600	6 12	52 71	32,076	3,865	..	12 05		7 62162
Total, .	.			7,09,945		18 84	169 43	1,20,678	6 264	291			
	..	.	.			.	.		5,973				..
Averages, ..	.		.	1,77,261		4 71	28 24	.		..	4 96		

* Figures marked thus in Columns 4 and 6 to be omitted in striking averages—the area irrigable from the Loosanee and Kabra tanks being very small in comparison with their cubic contents

NOTE BY CHIEF ENGINEER

Lieutenant Home's report conveys in the clearest manner and in the smallest compass a complete description of the subject, whilst the Appendices are stores of valuable information recording the whole conditions of the six principal tanks visited

The results of the inspection are that Colonel Dixon's works have not only enormously benefited the country, but that they have returned the Government Rs 150 per cent on the expenditure incurred They are reported to be in the most excellent state of preservation, and to be admirably maintained and managed at a very slight cost There is no establishment charged to irrigation, the work being done by Revenue establishment

The whole of the six tanks specially reported on, taken together, pay nearly 10 per cent on the capital invested, for Lieutenant Home's "nearly 5 per cent" is all clear profit, after paying interest charge at 5 per cent. and all expenses Evidently the management is very efficient, and an Irrigation Tehseeldar might probably be imported or promoted into Bundelcund with advantage And the enhancement of land revenue, allowed to be due to irrigation in Mhairwara and Ajmere, bears a very striking contrast to that which the Revenue Authorities in North-Western Provinces are disposed to assign to the same cause

The effects of administration must necessarily be judged from averages, but the most useful lessons for the future construction of tanks of irrigation are to be gathered from extreme cases.

Thus a review of No 6, "Nearan" tank, shows that when a million cubic feet of water can be stored for Rs 2,300, and can be made to irrigate 8 6 acres, paying in water-rent and enhancement of revenue Rs. 6 per acre, a profit of Rs. 17 per cent may be obtained on capital expended

On the other hand the statistics of No 5, "Duiathoo" tank, demonstrate that even when water can be stored in large quantities, at Rs. 1,820 per million cubic feet, and the land irrigated pays Rs 6 per acre, there is a loss when the land irrigated amounts to only 3½ acres per million cubic feet of water stored.

And the following results may be taken as axioms in tank irrigation :—

1*st* —That it is possible under very favorable circumstances to store water at a cost of Rs 133* per million cubic feet, and to obtain a return† of Rs. 17 per cent. on capital expended.

* No. 1, Tank Loosanee † No. 6, Nearan.

2nd.—That the Khureef irrigation of one crop, and so much irrigation as is necessary to secure the Rubbee crop on the same land may, under favorable circumstances, be effected by the use of about 116,000 cubic feet of water* per acre.

3rd —That no project of tank irrigation should be taken up unless a gross return of Rs 6 per cent. on outlay can be ensured from water-rate and enhancement of revenue combined.

4th —That the determination of area irrigable and amounts obtainable per acre on these accounts should precede all other investigation of tank projects

5th —That the water bearing surfaces of all bunds of tanks should be faced with masonry set in mortar

* No 6, Nearan

No. CCXXX.

ADJUSTMENT OF THE DUMPY LEVEL.

By H. Wilberforce Clarke, Lieut, R.E.

The process of adjusting Mr. Gravatt's Dumpy Level, and that is the Level now generally used, is a very troublesome matter, and, as the process, so far as the collimation is concerned, is most carefully considered, by Professor Rankine, in his work on Civil Engineering, a work which is not in the possession of all, all that I have to say will be based upon his method.

The permanent adjustments of the Dumpy Level are three in number

(1) To place the cross wires in the axis of the telescope

(2) To make the line of collimation and the spirit level parallel to each other

(3). To place the telescope and spirit level perpendicular to the axis "

(1) *To perform the First Adjustment*—Drive three pegs into the ground, at equal distances apart from each other, say $1\frac{1}{2}$ chains.

Call these pegs *a*, *b*, *c*.

Place the level midway between *a*, *b* and exactly in the line between them, make the temporary adjustments

Take the reading of the staff at (*a*); let it be *a*, turn the telescope, re-level it, if necessary, and take the reading of the staff on *b*, let its reading be *b*. Remove the level to a point, in a line with, and midway between *b* and *c*; make the temporary adjustments.

Take the reading of the staff on b, let it be b', turn the telescope, re-level it, if necessary, and take the reading of c, let its reading be c

Since the instrument has been placed midway between a and b, the errors of adjustment affect both alike, the same remarks apply to b' and c.

Assume, at a convenient depth A, a Datum level.

Then, correct elevation of b, above datum is .

$$B = (A + \overline{a - b}) \quad \ldots \quad (1)$$

And correct elevation of c above datum, is .

$$C = (B + b' - c)$$
$$= (A + a - b + b' - c) \quad \ldots \quad (2)$$

Now place the level at the shortest distance beyond a, at which it is possible to read the staff at (a); make the temporary adjustments and, having the instrument in a line with all three staves, read them on a, b, c

Let the readings be a'', b'', c''.

Then, apparent elevations of b and c, above datum, are

$$B' = (A + a'' - b'') \quad \ldots \quad (3)$$
$$C' = (A + a'' - c'') \quad \ldots \quad (4)$$

Compute the errors of those apparent elevations, if any:

$$(B' - B) \text{ and } (C' - C)$$

Then, if the wires be in the axis of the telescope, we shall have

$$(C' - C) = 2\,(B' - B)$$

If this be not so, shift the diaphragm as follows:

Direction of error (C′ − C)	(C′ − C) More than 2 (B′ − B)	(C′ − C) Less than 2 (B′ − B)	
Upward, ...	Upward	Downward.	Direction in which the wires are to be moved
Downward, ...	Downward	Upward	

(2). *To make the line of collimation and spirit level parallel to each other.*—Without removing the level from its position, at the shortest distance from (a) and having the wires in the axis of the telescope, direct the telescope, by means of the plate-screws till the reading of the staff at c is .

$$C_2 = (a'' - \overline{C - A})$$

$$\text{if } \overline{C - A} = x\,,\ C_2 = (a'' - x)$$

$$\text{if } C - A = -a\,,\ C_2 = (a'' + x).$$

Note.—$\overline{C - A} = (-a)$ when the ground slopes downwards from (a).

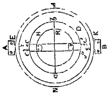
Bring the bubble of the telescope to the middle, by means of the screws which attach it to the telescope

(3). *To place the telescope and spirit-level perpendicular to the vertical axis* —Place the telescope over a pair of plate-screws, and, by turning them, bring the bubble to the centre of the spirit level, reverse the direction of the telescope, exactly, by turning it through 180°, about the vertical axis; if the bubble be still, in the middle, the adjustment is correct, if not correct half the deviation by the plate-screws, and the other half, by the screws which connect the telescope with the flat bar on the top of the vertical axis.

OBSERVATIONS

A few remarks seem to be necessary. We will first speak of the screws

Fig 1



Let *Fig* 1 represent a section of the telescope tube, at the focus of the object and eye-glasses Then N K M is the metal ring of the telescope tube, H *b* D *a* is the diaphragm to which are affixed the wires *ef*, *cd* vertically, and *ab* horizontally, A and B are the adjusting screws

The wires may be of spider's web, or of spun glass, or of platinum, in the event of the wires being broken, and neither spider's web, spun glass or platinum being obtainable, the ultimate filament of a piece of white silk thread will answer.

The wires are affixed by gum or shellac to the diaphragm *ecbda*.

The screws A and B are capstan headed, and thence are moved by lateral instead of vertical pressure

From an inspection of the figure, it will be seen, that by tightening, or screwing B (having, previously, loosened or unscrewed A) the diaphragm carrying the wires will be brought down towards K, or lowered;

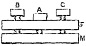
on the contrary, by loosening B and screwing A, the diaphragm will be raised towards E

Hence we have the means of vertical motion; and the diaphragm is drawn towards that screw which is being screwed or tightened.

The screws, by which the bubble tube are screwed to the telescope tube, are of the form shown in the diagram

At one end they are provided with the ordinary square cut by which vertical pressure, combined with lateral pressure, is communicated. These screws, unless it be necessary to increase the space between the bubble-tube and the telescope, should never be touched.

Fig 2



At the other end, though of the same form, the screws are furnished with capstan-heads, by these the adjustments of the bubble-tube, are effected.

Supposing, in *Fig.* 2, F to be the plate attached to the bubble tube, and M a projection, or square, on the telescope tube, we have·

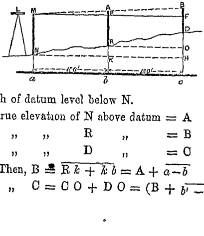
The screw A uniting the two, and the screws B and C pushing the plate F from the square M, the screws B and C are always in opposition to the screw A.

After the same manner is the telescope tube attached, in the new instruments, to the flat-bar, resting on the vertical axis.

Before tightening any screw, it is, always necessary to loosen the screw or screws, in opposition

Fig. 3.

Datum level In *Fig* 3 —



A = a N the depth of datum level below N.

True elevation of N above datum = A

" " R " = B

" " D " = C

Then, $B = \overline{Rk + kb} = A + \overline{a-b}$

" $C = CO + DO = (B + \overline{b' - c})$

And,

$$B' = A\,b = \overline{K\,b + b\,A} = (A + \overline{a'' - b''})$$
$$C' = B\,c = \overline{c\,H + H\,B} = (A \times \overline{a'' - c''})$$

Since ac is equal to $(2 \times a\,b)$, the error BF must equal $(2 \times A\,P)$

$$\text{or } (C' - C) = 2\,(B' - B)$$

if the wires trace out a right line

If $(C' - C)$ be $(+)$, the error is upwards

,, $(C' - C)$ be $(-)$, ,, is downwards.

The proper reading of the staff over the 3rd peg c, the level being at L, is $FD = C_2$.

$$\text{Now } C_2 = FD = (cF - cD) = (aM - Dc)$$
$$= A\,\overline{(+ a'' - C)} = (a'' - \overline{C - A})$$

Let $\overline{C - A} = (+ x)$ then $C_2 = (a'' - x)$

,, $\overline{C - A} = (- x)$ then $C_2 = (a'' + x)$

INDORE, CENTRAL INDIA,
18*th March*, 1869.

H. W C

No. CCXXXI

THE CEYLON RAILWAY.

By Guildford Molesworth, Esq., C.E.

The Railway was completed in October, 1867, and the line fully opened for traffic on the 1st of that month, although passengers and a limited quantity of goods had been carried for some time previously.

The cost of the line, exclusive of interest on debentures, and after making a fair deduction for the exceptional expenses incidental to the formation and dissolution of the late company, amounts to £1,436,127 or about £19,148 per mile,—a cost which, (considering the rugged character of the country, the excessive unhealthiness of a large portion of it, and the fact that the labor of Ceylon is almost entirely imported,) may be considered extremely moderate It may not be out of place to recapitulate briefly the causes which have led to the exceptional expenditure to which I have alluded above.

In the year 1847 a Company was formed for the construction of a line from Colombo to Kandy, and the concession of a guarantee, on the Indian principle, was sought from Government, but it was not until 1856 that a Provisional Agreement was made between the Government and the Company The terms of the guarantee were 6 per cent. on all capital not exceeding £800,000, and 5 per cent on all capital expenditure beyond that amount

Before this concession was ratified, it was deemed expedient that an Engineer on the part of Government should examine the country, with the view of reporting whether the railway could be constructed within the amount for which the Colony was willing to grant such a guarantee, and at the beginning of 1857, Captain Moorsom was sent out by the Secretary of State for that purpose, his staff of Surveyors having been sent out a month in advance of him His Report, dated two months

after his arrival at Galle, deals with the respective merits of six different routes, averaging from 80 to 100 miles in length, through a country probably unequalled for the obstacles it presents to reconnoissance and survey.

It is not surprising that the results of so hurried an estimate should have proved fallacious

The route selected by Captain Moorsom was identical (excepting some slight modifications) with that selected by Mr Drane, who had previously surveyed the country for the Railway Company It took the general direction of the present line for thirty-five miles, and thence skirted the *south* bank of the Maha Oya, as far as the 57th mile, it then diverged up the Hingula, Gadadessa, and Parnapettie Valleys to Ilukwatta, about nine miles from Kandy, and thence along the present trace to Kandy The length of this line was eighty miles, and Captain Moorsom's estimate for the single line was £856,557, including land, works, stations, rolling stock, management, and contingencies. The concession was therefore granted by Government to the Company, and a staff of Engineers was sent out under Mr. Doyne, the Company's Chief Resident Engineer, at the end of 1857

It soon became apparent, however, to Mr Doyne that the estimate of Captain Moorsom, so hurriedly framed, was wholly insufficient for the completion of the line, In working out the details of the line selected, the proposed gradient of 1 in 60 had to be reduced to 1 in 50, and it became necessary to introduce two reversing stations on the incline, whilst the proposed works were of a very heavy character, and being of opinion that the line selected was the best that could be obtained for a *Locomotive* Line, Mr. Doyne attempted to reduce the cost by ascending the mountain passes with a *Stationary Engine* Incline, about three miles long, with gradients of 1 in 16. The cost of this he estimated at £2,214,000

Surprised and alarmed at the enormous discrepancy between these estimates, the Government determined, in August, 1859, that the question of probable cost should be referred to Mr Robert Stephenson, and that Mr Doyne should proceed to England, taking with him the plans, sections, and other data necessary to enable Mr. Stephenson to arrive at a conclusion on the subject The death of Mr Stephenson, before he completed this investigation, and the subsequent reference of it to Mr Hawkshaw, entailed so much delay that it was not until June, 1860, that Mr. Hawkshaw made his report.

The views expressed by Mr Hawkshaw were, that a Stationary Engine Incline was inadmissible, and that a modification of Captain Moorsom's route might be made by reducing the railway gradient to 1 in 40, but that the line could not be constructed, and stocked, under any circumstances, for £1,500,000, though it might be for £1,827,000 At this period, I was acting on behalf of the Company as their Chief Resident Engineer and Agent, and during the year which elapsed, pending this reference, I employed the Engineering Staff (with the consent of the Government) in surveying a new route, which appeared to me to give greater facilities for a *Locomotive* line through the mountain passes, than that selected by my predecessors.

The results of these Surveys were highly satisfactory, the new trace *viâ* Deekanda effected a saving of five miles in the length of the works on the Pass the works were lighter mile for mile, and the soil less treacherous than that of the Valley of the Gadadessa The advantage gained on the incline alone, I estimate at more than £300,000 In addition to this, seven miles of excessively heavy work along the banks of the deadly Maha Oya have been avoided, and the experience of this river shows that it is impossible to calculate what additional cost such extensive works on its banks might have entailed. The cost of the line was further reduced by transferring the trace from the south to the north side of the river, as suggested by Mr Doyne, shortly before his departure.

The Colony however, dissatisfied with the uncertainty involved in the guarantee to the Company, decided upon the dissolution of the contract by mutual agreement, and this was effected towards the close of 1861.

At the date of dissolution, the expenditure was £382,138 this included interest to shareholders, preliminary expenses, the cost of Captain Moorsom's mission, and the expenses of the Acts for the formation and dissolution of the Company. Out of this the assets available for the construction of the Railway, in land, works, materials, permanent way, surveys, and cash, were only £125,000

To complete the railway, the following expenditure has been necessary, under contract with Mr. Faviell, ...	£873,039	
Beyond the contract, after deducting interest on debentures, and stores in hand	438,088	1,311,127
Total, ...		£1,436,127

On the 2nd of February, 1863, a contract was concluded between the Government of Ceylon and Mr Faviell, for the construction of the line in four years, but, in consequence of the excessive sickness in the unhealthy districts, the term of completion was extended to four years and eight months, and the Government has paid to the contractor an additional sum of £58,202, in consideration of the unusual difficulties experienced by him in the construction of the line

The only portion of the contract which has not worked satisfactorily is that affecting the expenditure on stations

The railway has been well and substantially constructed; the way and works have been kept in efficient repair during the past half-year, and the permanent way is now in excellent running order I annex a Statement showing the leading characteristics of the railway

At the break of the monsoon, the traffic was interrupted for a few days by heavy landslips accompanied by boulders on the incline, but such interruption must be expected during the break of the monsoons for many years to come The slips were however rapidly cleared, the fencing is in better order, but still very liable to gaps towards the end of the dry season, owing to the ravages of the white ants, and the trespass of buffaloes The adoption of cow-catchers has however reduced to the minimum the risk from cattle trespass

The results of the opening of the line have been very satisfactory, and the traffic greater than I had expected for the first year The traffic has come upon the railway in a manner which has seriously tested its powers. Most of the carts formerly plying between Colombo and Kandy were suddenly released to ply between the estates and the railway termini, thus causing a flush of traffic on the railway, which I believe is exceptional, and scarcely likely to happen again, as the decrease of cart licenses in the Western Province from 8,000 to 4,000, is unaccompanied by a corresponding increase in the Central Province, and the export returns show that on the 26th December, 1867, the exports of coffee were 75,000 cwts in excess of the shipments at a corresponding date on the previous year

The opening of a railway in a new country is invariably attended with great difficulties The clerks, porters and signallers are necessarily untrained and inexperienced, and the freighters and station-masters new to the all necessary arrangements But the Ceylon railway had to contend

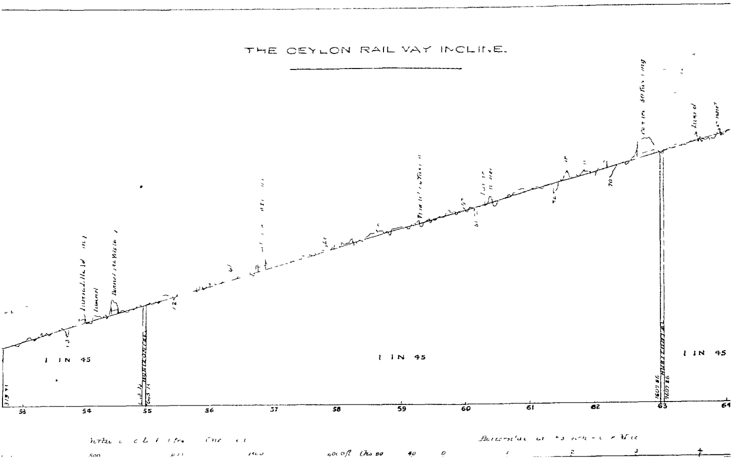
with an unusual share of such difficulties. The drivers and breaksmen were unaccustomed to work such a gradient as that on the incline, the flush of goods glutted the stations, and the break of the monsoon occurred shortly after the opening, obstructions consequent on landslips caused the traffic to accumulate at the termini, the telegraph, scarcely completed, was not in good working order, and the rolling stock was short of its proper complement by forty-nine wagons, owing to the late arrival of English consignments, all added to the difficulties inseparable from such an undertaking, but notwithstanding these impediments, the opening has been very satisfactory. There was a glut at the stations for a few days, but it was quickly relieved, and the traffic was carried down in a manner which reflects the greatest credit on the arrangements and efforts of the Traffic Manager and the Locomotive Engineer.

The following statement shows the chief characteristics of the Ceylon Railway

Total length, 57 miles, single line.
Formation width, 20 feet, 18 feet in rock cuttings.
Weight of rails, 72 lbs per yard.
Gauge, 5 feet 6 inches
Sleepers, 9 feet 9 inches long × 10 inches × 5 inches
" average distance apart, 3 feet.
Two additional sleepers per length of rail on the incline.
Length of incline, 12 miles
Ruling gradient on lower portion of the line, 1 in 100.
Gradient of incline, 1 in 45 throughout.
Majority of curves on incline, 10 chains radius.
" of " on the lower portion, 20 chains radius.
Number of tunnels on the lower portion of the line, 1
" on the incline, 10.
Length of longest tunnel, 365 yards.
Number of Stations, 10.

COLOMBO,
9th June, 1868. G. L. M.

THE CEYLON RAILWAY INCLINE.



No. CCXXXII.

CONCRETE ROADS

To the Editor.

DEAR SIR.—I have the pleasure to send you copy of a brief Memo by Major R Malcolm, late of the Bombay Engineers, on Mitchell's System of Concrete for Roads It is thought that it may be found useful in India, and I know of no better way of giving it publication than by asking you to give the Memo a place in the very valuable collection of Engineering papers published under your superintendence

KURRACHEE COLLECTORATE, *Camp Tatta Bunder*, *16th April*, 1869.

Believe me,
Yours truly,
W. MEREWETHER, COLONEL,
Commissioner in Sind.

Memo by Major Malcolm on Mitchell's Concrete Roads

The concrete roadway contrived by Mr Mitchell consists of a crust composed of broken stone and hydraulic cement

A thickness of 6 inches is found sufficient for ordinary circumstances.

The advantages claimed for it are—

1st. The complete exclusion of moisture from beneath and rain water from above, which are important elements of destruction in a Macadamized road

2nd. Uniformity of surface and consequent ease to passing traffic from the day the road is laid down.

3rd. Durability and consequent economy, this latter point being set down at a saving of 50 per cent on the cost of making a Macadamized road and maintaining it in good order for 10 years.

From personal inspection I can state that the first two points appear to be perfectly attained

As regards durability I have learned that an experimental portion laid down a year or two ago in London proved unsuccessful I have endeavored to ascertain the cause of this Mr Mitchell ascribes the failure to the fact of his being unable from illess to superintend the preparation of the experimental roadway in St James's Park, in which defective cement was unfortunately used, and over which the traffic was allowed to pass before consolidation had taken place.

Against this instance I can only cite the case of a road in the yard of the railway station at Inverness, which for some years past has been subjected to the daily passage of a very heavy traffic without sustaining more wear and tear than has from time to time been made good by a small patch applied with a mason's trowel. For upwards of two years its surface appears to have been absolutely unimpaired

Again on George the IV.'s Bridge at Edinburgh, I saw a portion of this roadway which had been in constant use on that much frequented line of traffic for upwards of a year, no signs of ruin were apparent.

It appears to me that for roads over the alluvial plains of India where *metal* is often unprocurable, except from considerable distances, this causeway might prove serviceable.

Its adoption would reduce the amount of stone required for a road by a ratio of one-third compared with the Macadam prescription, while under the light traffic of India. it might remain unimpaired for many years During the annual rains of the tropics it would remain well agglomerated, instead of being first soaked and afterwards disintegrated as ordinary metalled roads are apt to become in the East.

From its earliest stage it would afford easy traction to the bullocks of the country, which at present are often so injured in the feet by drawing carts over a rough road newly metalled that the owners prefer to lead them clear of it and proceed across country in fox-hunting fashion

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Considering the high price of Kunkur and Stone Metalling in this part of India, it would be worth trying a concrete Road made with vitrified brick instead of stone.—[ED.]

No. CXXXIII.

LESLIE'S PATENT ROOFING.

Specification of Improvements in the Construction of Arches applicable to Roofs, Floors, and Bridges, or other Arched Buildings.

THIS invention consists in the formation of Arched Roofs, Floors, and Bridges, &c., by a combination of iron, tiles, or stones, in such a manner that the usual centering required for building masonry arches is dispensed with, at the same time that strength, lightness, and economy are attained in a very high degree.

Arched ribs of bar-iron are fixed at regular intervals across the area to be covered or spanned. The ends of these ribs may be built into masonry or brickwork, or may be secured to wall-plates of timber or iron by bolts or rivets, or in any other manner that may be convenient, such wall-plates resting upon piers, abutments, walls, or arcades, or fixed to the top of columns of metal, timber, stone or brick

The inventor recommends the adoption of bar-iron of the section of an inverted letter (T) thus (⊥), but double angle-iron rivetted back to back, or single angle-iron with a flat bar rivetted on the bottom of it to form a (⊥) shaped section, or single angle-iron placed, like an inverted letter (L) thus (⅂), or, in small spans, flat bar-iron may be used. In short, the section of iron to be used depends greatly on the description of iron available.

To keep the ribs straight and parallel during construction, and to preserve the proper interval between them, inner longitudinal ridge pieces or purlins of bar-iron or timber may be fixed temporarily or permanently to the underside of the arched ribs at the crown of the arch, and at the haunches if required, and in arches of large span, these ridges or purlins may be temporarily supported on props to preserve the correct versed sine or rise of the arch during construction.

In arches of very large span, simple ribs of bar-iron would not of themselves afford a sufficient degree of vertical stiffness. In this case the necessary amount of vertical stiffness may be obtained by introducing, at intervals of from 6 feet and upwards, a stiffening rib of increased vertical depth formed by combining top and bottom angle or $\perp$ irons with a vertical web-plate or lattice bracing. The ridge pieces or purlins being secured to such stiffening ribs, will afford the necessary amount of support to the ordinary intermediate ribs.

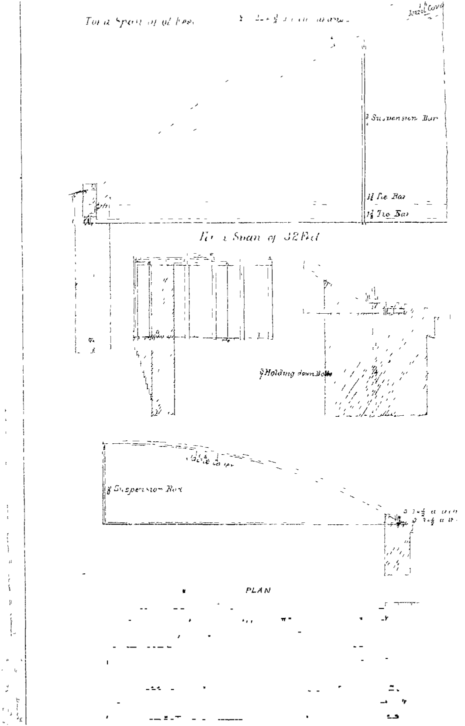
Tie-bars are required at intervals to prevent the abutment walls or columns from spreading outwards, unless these latter are strong enough to resist the thrust of the arch, or the thrust may be counteracted or neutralized by adjoining arches, floors, or roofs.

Upon that surface of the ($\perp$) iron or other bar-iron used for the ribs, which is horizontal in transverse section and starting either side from the wall or wall-plates as an abutment, stones or tiles spanning the interval between each pair of adjoining ribs are laid in close contact with each other until they meet in the centre. The arch of stones or tiles so formed is set in cement or mortar.

If the arch is intended for a roof, a second layer of tiles or stones set in cement or mortar, or a thickness of well-beaten concrete may be laid on top of the first layer, or any of the ordinary methods may be adopted to to make the roof water-tight

If the arch is intended for a floor, the spandrils may be closed in by building spandril walls over the iron-ribs; the intervals between the spandril walls being covered by tiles or stones, forming a level floor or terrace

If the arch is intended for a bridge to carry heavy moving loads, one or more arched rings of masonry or brick-work may be built on top of the first layer of tiles or stones, and, if necessary, the spandrils may be filled up with a backing of concrete. By this means arches


Suspension Bar
Tie Bar
Tie Bar
For a Span of 32 Feet
Holding down Bolts
Suspension Rod
PLAN

of great strength may be built without the ordinary centering being required.

The inventor does not claim as part of this invention the application of ⊥ iron or other bar-iron to support by its transverse strength the covering of roofs or floors, as burgahs or purlins carried by beams, joists, or rafters are used in ordinary flat or trussed roofs or floors. What he does claim is the application of materials of the scantling ordinarily used for burgahs or purlins to form arched ribs, spanning the total width to be covered or bridged, thereby affording a convenient means of erecting a thin arch of tiles, stones, or brick-work without the centering usually required.

It is an essential feature of this invention that, while the iron-ribs by themselves, in some cases, might not possess sufficient lateral stiffness to resist the thrust due to their arched form, and, in the same manner, the arch of tiles or stones alone would be deficient in the vertical stiffness necessary to support unequal strains, the combination of the iron-ribs with the tile or stone panelling between them presents a structure of extraordinary strength and stiffness.

Thus the deficiency of lateral stiffness in the arched iron-ribs is perfectly obviated by the confinement of the vertical web of the ⊥ iron between the panelling of stones or tiles on either side, and the want of vertical stiffness in the stone or tile arch is supplied by its combination with the arched iron-ribs. On this account, if a joint or joints are unavoidable in the arched iron-ribs, the vertical flanges or webs should be scarfed with a long lap, or the joint should be covered by a piece of ⊥ iron or angle-iron rivetted to the underside of rib, so as to preserve the vertical stiffness as much as possible.

This system of arching when applied to roofs and floors, has many advantages, among which are strength; durability, lightness, facility for drainage, security in case of settlement in the supporting walls, economy in the saving of the main beams, joists, or rafters required for ordinary floors or roofs, and in saving the centering for ordinary arches; and it has the advantage of being very expeditiously constructed.

By the adoption of roofing constructed on this system a saving is effected, of from eight annas to one rupee per superficial foot, as compared with any other system of permanent roofing.

Terms for using this invention together with detailed drawings and quantities of iron-work may be obtained on sending particulars to

BRADFORD LESLIE,

Eastern Bengal Railway, Calcutta.

*** This is a very simple kind of roofing and made very quickly, and any mistree can curve the T or angle irons into shape on the spot without difficulty. It is somewhat like the iron roofs used in the N. W. P. Railway Stations, which have iron arched girders 12 feet apart, connected by T iron purlins, on which rest flagstones about 2 inches thick with caulked joints. These roofs, however, being much acted on by the wind, cause the joints to open and the roof covering is apt to leak. In the *present system, the struts and ties are dispensed with, while the trusses are placed close together* (very much smaller T iron being used) so as immediately to support the roof covering which is usually *double*, and *perfectly water-tight*.

CALCUTTA,
March, 1869

F. F.

No. CCXXXIV.

SHRINKAGE OF EARTH IN EMBANKMENTS.

To The Editor.

SIR,—It has been asserted by some authorities, notably by Gillespie, at page 119 in the 9th edition of his work on "Roads and Railroads," that earth looses in bulk when excavated and placed in embankments; and this author states that the allowance for "Shrinkage" in the New York Public Works varies between 8 and 15 per cent.

It does not appear that the above law holds good for Indian earthwork, as the following experiments, undertaken with regard to certain contract measurements, go far to prove.

Black Soil.—A trench $49' \times 4\frac{1}{4}' \times 2'$, containing 416 cubic feet was dug, and the stuff from it formed into a bank which measured $50' \times 6' \times 2' = 600$ cubic feet.

The immediate *increase* thus appears to have been 45 per cent.

A portion of the earth was afterwards filled back into the trench, and when it was brought up level, a balance of 191 cubic feet remained over; this is a confirmation of the above result.

During the rainy season the trench was replenished, from time to time, as the earth sank, and at the close of the monsoon, the balance was reduced to 22 5 cubic feet.

The *ultimate* excess seems therefore to be 5·3 per cent in this soil.

Red gravelly soil or Moorum.—This is an iron-stone gravel mixed with about 50 per cent. of red earth.

A trench $49\frac{1}{2}' \times 4\frac{1}{4}' \times 2' = 420$ cubic feet, was dug in this soil, and

the stuff from it formed into a bank which measured $49\frac{1}{2}' \times 6' \times 1\frac{3}{4}' =$ 520 cubic feet, giving an excess of 24 per cent.

Also another trench, $49\frac{1}{2}' \times 4\frac{1}{2}' \times 2' = 445$ cubic feet, gave, when the stuff taken out of it was filled back into it, an excess of 111 cubic feet = 25 per cent

After the rains the resulting balance was only 55 cubic feet, wherefore the ultimate excess in this description of soil appears to have been $12\frac{1}{2}$ per cent

It is to be expected, therefore, that in course of time all excess would disappear, and that the earth would recover its original density. My experiments, as far as they go, certainly cast a doubt on the statements of those who say that earth *Shrinks*, when excavated, they also bear out the common sense view of the matter, but I should hope that if you will kindly publish the above, some of your readers may be induced to add to our information on the subject, from their own experience, and thus set the matter completely at rest one way or other

Yours obediently,

J H E H.

DHARWAR,
14th March, 1859

No. CCXXXV.

INDIAN WEIGHTS AND MEASURES.

Proposals relating to the introduction of New Standards of Weight and Measure in British India BY COLONEL R STRACHEY, R E, F R S. —*Dated 1st October*, 1867.

THE diversity among the weights and measures used in various parts of India is as great as is well possible In this, however, India in no respect differs from other countries in which uniformity has not been prescribed by authority

Throughout India the old standard of weight seems almost universally to have been the current coin of the locality, and the multiplicity of coinages has been, and is still, accompanied by an equal or even greater multiplicity of weights Not only do the weights vary from province to province but from town to town, and even within the same town or rural district. Different weights are used in various trades in the sale of different commodities, and in wholesale and retail transactions

In Northern India, the usual unit of weight is the *tola*, which is the weight of the current rupee coin. The *seer* is a given number of tolas varying from 70 to 100 The *mun* (by the English commonly called maund), is usually 40 seers A weight of 5 seers called *pusseree* is generally recognized, and the *seer* is sub-divided into 16 *chittacks*. The rupee of the British Government weighs 180 grains, the seer of the British Government, being 80 tolas, is equal to $2\frac{2}{35}$ lbs avoirdupois, and the Government maund is $82\frac{2}{7}$ lbs. avoirdupois, or 100 lbs. troy. Local seers and maunds vary on either side of 2 lbs avoirdupois, and 80 lbs. avoirdupois

In Southern India, the original unit of weight commonly used was the

pagoda, a coin no longer current The common kutcha seer was 80 pagodas, and was equivalent to 24 current rupees The maund of Southern India usually contains 40 such seers, and is commonly divided into 8 *viss*, or five seer weights, and 40 *pollums* The *candy* of 20 maunds is another weight in ordinary use At Madras, the Government, some years back, endeavored to establish a local system of weights on the basis of the rupee weighing 180 grains The seer was not acknowledged in this system, but would be 0 617 lbs The viss was 3 086 lbs., and the maund 24 686 lbs This system, however, never came into use In practice, the commercial maund in the town of Madras is taken at 25 lbs. avoirdupois, and the viss and candy are modified accordingly, but beyond the municipal limits other weights are employed The weight in common use in Burmah is called viss also, it is 3 65 lbs, and is subdivided into 100 *ticals* each of 252 grains.

In Guzerat, a seer of 40 local rupees weight, a maund of 40 such seers, and a candy of 20 maunds, are the common weights These maunds vary from 37 to 44 lbs, and seers are about 1 lb

In Malwa, a seer of 80 local rupees weight, and a maund of 20 such seers, are common This maund is approximately the same as the Guzerat maund, the seer being about 2 lbs, as in Northern India

At Bombay, the old seer was about 10 or 12 oz avoirdupois, being reckoned as equal to 30 pice. The Bombay maund being 40 such seers is nearly 28 lbs, at which it is now commonly reckoned. This maund is the usual one also on the Malabar Coast, south of Bombay, but the seer is the Madras one of 24 rupees weight, so that the maund consists of 46 to 48 seers instead of 40 At Bombay and in the Deccan, the sub-division of the seer is into 72 parts called *tank*. The Deccan seer is commonly 80 of the local rupees, or about 2 lbs, the maund varies greatly In the Deccan, the weights seem to merge into the Madras systems on the one side, and into the systems of Malwa and Northern India on the other

Measures of capacity are hardly known in Northern India In Bengal and Southern India they are more frequently used, and, as a rule, are intended to be equivalent to certain determinate weights of grain In Burmah, grain is universally sold by measure. There is, however, such great variation among measures having the same name, that it would be useless to refer to them in detail.

The usual lineal measures are the cubit or *hath*, and the yard or *guz*, the latter being divided in Upper India into 16 *girahs* or 24 *tussoos*. The hath varies from 14 to 20 inches; the guz from 28 to 40 inches. Thirty-three inches is the length assumed for the guz in fixing the official land measures in the North-West Provinces. The *coss* is sometimes taken to be 4,000 guz, about $2\frac{1}{4}$ miles, and sometimes half that distance; but 5,000 guz, equal to about 4,500 yards, or $2\frac{1}{2}$ miles, would seem to have been the old coss of North-Western India.

Measures of area are commonly based on the hath or guz, but vary so exceedingly from one district to another, that no general account can be given of them. Frequently the denomination of the land measures is the same as that of the grain measures, it being understood that the quantity of grain in a given measure will sow the area of land having the same name. It is common in Southern India to find the land measure of the same name differ considerably according as the crops are irrigated or un-irrigated. For all Government purposes, the English acre has now almost universally been adopted, and the revenue records are, I believe, almost everywhere drawn out on this basis, though the local measurement is at the same time still recognized.

The immediate conclusion forced upon us, on a review of such a condition of things, is, that to establish uniformity, it would become necessary to set aside what may practically be said to be the whole of the existing weights and measures of all sorts It might be found possible to devise new systems which should in their main features be in harmony with the existing systems of considerable parts of India, but in detail, almost the whole of the weights and measures in actual use would have to be replaced by new ones, whatever plan might be adopted. Even if the British Government seer and maund where taken as the new standards, this would hold good, for, although their use is no doubt more general than that of any other description of weights, yet it is in fact very limited when we regard the whole extent of British India.

To some persons it will no doubt appear questionable whether, under present circumstances, the introduction of uniformity in the weights and measures of India should be attempted, and whether, if attempted, it could be enforced But into any detailed discussion on these subjects I shall not here enter, nor indeed could such discussion be properly undertaken until a clear idea had been first obtained of the nature of the

changes that would be required, and of the best manner of making them It will, therefore, be sufficient in this place if I assume that the attempt shall be made, and that we have only to consider in what way it may be best made, I may, however, state my own conviction that, with suitable arrangements and due perseverance, the ultimate attainment of uniformity may be regarded as quite feasible But I must guard this expression of opinion by adding, that the practical importance of establishing uniformity of *weights* seems to me to stand on a decidedly different footing from that on which rests the expediency of reforming the *measures* of length, area, or capacity, also that there is much to be said in favor of not attempting too much in this direction at one time, whether regard be had to the probable difficulty of commanding the common consent of Englishmen interested in the matter, or of overcoming the passive resistance of the people of India.

Both in respect to the internal convenience of India itself, and to its external relations with the rest of the civilized world, the determination of the standard of weight is of far greater importance than that of length, area, or capacity The retail transactions of every-day life bring home to the whole population the nature of the weights by which commodities are sold, whereas the determination of distances or areas is rather restricted to peculiar classes, and then under circumstances which do not immediately affect the ordinary business of life. Where measures of capacity are practically based on weights, as I believe is almost universally the case in India, the former are entirely subsidiary and ancillary to the latter.

I shall, therefore, commence with the consideration of the weights. In doing this, I am fully aware that a scientific treatment of the abstract question of the most convenient metrical system should begin with a discussion of the unit of length. But I do not concern myself with any such abstract treatment of the subject. Whatever conclusion is come to, it is certain that it will not lead to the adoption of an absolutely new unit of length or weight, all that we have to do is to select for India some one of the existing standards which have already obtained the sanction of custom All standards of this sort are essentially arbitrary, and have very little in them to recommend one rather than another. The reasons that induce me to select a particular one from among them, are, as I shall point out in the sequel, of a purely practical nature.

It will first be convenient to say a few words on the existing Govern-

ment system of weights, established under Regulation VII. of 1833, (referred to in page 1 of this article) This was introduced on the advice, I believe, of the late Mr James Prinsep. Following the old native idea, it is based on the rupee coinage Even as a system for permanent use exclusively in India, there would be little to recommend it; but no serious attempt has ever been made to bring it into use in the country at large, and it may in general terms be said to be unknown out of the chief towns near which a large English society has grown up.

This system of weights in its relation to English commerce is inconvenient in the extreme It is founded on troy weights, which are only used for the sale of drugs in retail, and of gold and silver, and it has no exact equivalents in avoirdupois weight, which is exclusively used in commercial transactions Both in the ascending and descending scale, it adopts the old cumbrous native method of division.

In a primitive state of society, where the adjustment of the weights of commerce is not under control, a system which adopts a fixed number of a common current coin as the standard of weight, has sensible advantages But as soon as the State interposes and prescribes a standard, it becomes essential, if the adoption of that standard is to be enforced, to establish the means of giving official authenticity to the weights used by dealers, of eliminating incorrect weights, and of supplying in their places those known to be correct The rude checks which, in a simpler state of society, customers may desire to exercise for their own protection, will then soon become obsolete, and all questions will be referred to the proper authority, whose business it will be to supervise the weights and measures of the place.

On this ground it seems of no special importance to retain any exact proportion between the weight of the current coin and of the unit of weight for commerce, though if such a proportion can be maintained it has some advantages An ideally perfect system of coinage and weights and measures would, no doubt, make the weights of the coins exact multiples or sub-multiples of the unit of weight, and the diameters of the coins exactly commensurable with the unit of length. But it must be borne in mind that in practice current coins, after ordinary use, vary so much in weight as to make them incapable of serving as exact standards, so that a test such as they can supply is far more rough than it might at first sight appear to be.

As regards the existing rupee weight or tola, I can attach no value to it as a permanent standard of weight. I feel satisfied that gold is destined to become the standard of the Indian currency, as it has become in almost all civilized countries, and when this happens, the fixity of the rupee becomes very doubtful. The permanence of the rupee is made questionable on other grounds also. The tendency among civilized nations to adopt a common monetary unit becomes daily more manifest, and that this end will eventually be arrived at I cannot doubt. A movement is now going on, under the sanction of the Emperor of the French, to effect this object As regards England, the very small difference that exists in the quantity of pure gold in the sovereign and in 25 francs of the French gold currency, amounting to a little less than 1 grain of pure gold, the value of which is about two pence, indicates that the change might there take place at any time Should it be carried out, the advantage of extending to India the conveniences of the arrangement might probably be pressed on the Government of this country in a manner which it would be difficult to withstand, and if the common monetary unit of Europe were adopted in India, it must almost certainly lead to the modification of the rupee

On the whole, therefore, I conclude that the system of British Indian weights based on the tola, has no very strong claims to consideration, derived from any special convenience of importance, and that it is decidedly objectionable in not being commensurable either with the English weights of commerce, or with those of any other country with which India has commercial relations.

The reports of the local Committees appointed to consider the subject of Indian weights and measures are unanimous in rejecting the British Indian system as it now stands, and I am not aware that any authority has pronounced in its favor. The general opinion seems to be that a seer of 2 lbs. avoirdupois should be substituted in place of the existing seer, with a maund of 50 seers equal to 100 lbs. The sub-division of the seer into sixteenths is generally advocated.

Of proposals of this class it may be said that there seems no special convenience to the people of India in adopting a seer of 2 lbs. in preference to any other weight of nearly that amount; and that the English avoirdupois pound, being essentially the unit of retail and not of wholesale trade, is not a convenient unit for the commercial transactions between

India and England. For these, the hundredweight of 112 lbs., and the ton of 2,240 lbs, are almost exclusively used. A system of weights which should be decimally arranged with the pound as a unit, would practically be as incommensurable with the weight of English commerce, as the British Indian system is, and for the purposes of commerce, tables for the conversion of such weights would be just as necessary in every merchant's office as they are at present.

If it be admitted, as it seems to me that it must be, that it would not be more difficult to introduce into use in India by authority, any one unit of weight rather than another, provided they be equally convenient on general considerations, then it would follow that it is chiefly to considerations of general convenience that we must look in making our choice of a unit. So long as the amount of the change, which under any circumstances will have to be made in the weights of the country, is restricted within certain limits, its precise quantity is not important. It cannot make any appreciable difference to the natives of India whether, for instance, the seer which at any place is now say 1 lb 10 ozs. shall be altered to 2 lbs, or to 2 lbs. 1 oz, or *vice versâ*. The proposal to assume the seer to be 2 lbs, which has so generally been made, in fact admits this view to be correct.

Hence, so far as I can judge, the only important consideration which should influence us in our conclusions as to the precise unit to be adopted, is that the system of weights we select for India should conform to the systems in use in the rest of the world, and in particular to those in use in countries with which India has the largest commerce.

This conclusion would at once indicate that it is to the commercial weights of England to which we should first look in seeking a new unit for India. As I have before remarked, the pound, though the nominal unit of English weight, is not practically the unit of wholesale dealings, with which alone commerce concerns itself in an important degree. The ton being 2,240 lbs, and hundredweight 112 lbs., the expediency of adopting as the new unit a weight of 2 24 lbs avoirdupois, which is one-thousandth part of the ton, and one-fiftieth of the hundredweight, readily suggests itself. For the purposes of practical retail dealings this weight would be equal to 2¼ lbs. It would, on the whole, more nearly approximate to an average Indian seer, I believe, than a weight of 2 lbs, and so be more acceptable to the people of India. It would also be not

greatly different from the French kilogramme, which is 2 205 lbs avoirdupois, and for small quantities might be regarded as an equivalent. The difference between the kilogramme and 2 24 lbs being about $1\frac{1}{2}$ per cent, larger quantities would require a correction

But the question arises, when we have got thus far, whether it is possible to regard the present English system of weights as likely to continue in force for such a length of time as to preclude the necessity for considering in what direction it is likely to be modified? If India is to be kept dependent on England in respect to its weights, and if we are now to come to a conclusion regarding the Indian system, it seems essential to look forward to the probabilities of the English system in the future. It would be most objectionable to enter upon so important an operation as the fixing a standard for the weights of India, with the conviction that what is now done is not likely to be lasting. In such a matter the convenience of the people of India cannot with justice be set aside. One change is as much as can be fairly asked of them. To make an organic change now, knowing that some years hence a further organic change would be necessary to meet a change made in the English system of weights, would in my opinion, be utterly unjustifiable, and rather than accept such a result, I should prefer to see the present confusion prolonged. This consideration should have the more force if the precise character of the change first proposed were determined, as would be the case under the supposition made, not by any consideration of the convenience of the people of India, but exclusively in the interests of English merchants

I ask, therefore, is it likely that the present English system of weights will last indefinitely? My reply is that I do not believe that it will so last. The conclusion seems unavoidable that before long the French weights and measures must be adopted in England Even at the present time the greater part of Europe has adopted them Portugal, Spain, France, Italy, Belgium, Holland, and parts of Switzerland have accepted the entire system. The Zollverein, which includes all commercial Germany, also Denmark and Norway, have adopted the half kilogramme as the unit of weight. In Austria the same unit is said to be used in all great commercial operations. Several of the minor States of America have also adopted this weight. The weight of the German Union Dollar (Vereinsthaler) is based on the Zollpfund, or pound of the Zollverein, which is half a kilogramme, and the Austrian Gulden is also commen-

surable in weight with the Union Dollar Under such circumstances, and having regard also to the constantly increasing intimacy of the relations between the various countries of Europe, arising from the vastly improved communications and enlarged commercial transactions, I cannot but think that it is a mere question of time when the weights of England are assimilated to those of France and the rest of Europe It is right to remark however, that some of the Indian writers on this subject have given opinions to the effect that England is likely to adopt a hundredweight of 100 lbs avoirdupois, and a decimal scales of weights based on the pound But I cannot admit that there is the smallest probability of change being made in such a direction, if any alteration takes place, it will assuredly be of a much more sweeping nature

On these grounds I cannot avoid the conclusion that if any attempt be made to introduce uniformity of weights in India, we should at once adopt the French unit and take the kilogramme as the basis of the new system—a proposal already put forward by the Bengal Committee, and accepted by the Lieutenant-Governor of Bengal, Sir C Beadon As I have already observed, the kilogramme which weighs 2 205 lbs, is quite sufficiently near the existing seer weight of Northern India to be as acceptable as a 2 lb weight, and is probably more convenient so far as the people are concerned The average seer is in excess of 2 lbs, and a change which somewhat increases a weight is more popular than one which reduces it; the majority of the people being purchasers, and the sellers being comparatively few in number

To the English merchants settled in India, having dealings with England, the conversion of English weights into the new or French equivalents, would in fact call for no more trouble than is now needed, or than would be needed if the 2 lb unit were adopted. It is probable, indeed, considering the close approximation of the English ton to the French tonne of 1,000 kilogrammes, the former being 2,240 lbs, and the latter 2,205 lbs, giving a difference of only 35 lbs. or about $1\frac{6}{10}$ per cent, that the one might be accepted for the other, or that the simple addition or deduction of that percentage would be considered sufficient in converting English to French tons. The same remarks would apply to the hundredweight, which being 112 lbs would closely approxi-

1 Ton English = 1016 05 kilos
1 Tonne (1,000 kilos) = 98421 tons
= (1—0 1579) tons

1 cwt English = 50 80 kilos
50 kilos = (1—0 1579) cwts.

mate to 50 kilos or 110 23 lbs To English merchants in England, having dealings with India, the change proposed would only have the effect of extending to those dealings the system of conversion of weights which is already required in their transactions with the commercial nations of Europe, and therefore quite familiar to them, instead of requiring a change of a novel character, involving the creation of new standards, and adding a further load to the burden already put upon them by the existing diversity and complications of the weights they are forced to recognize.

The British Indian seer, weighing 2 057 lbs, is 0 9331 kilos This is very nearly $\frac{15}{16}$ths of the kilogramme, which would be 0 9375 kilos The difference amounts to 4 4 grammes, or one-half per cent If the kilogramme were adopted as the new unit of weight, and divided into sixteen parts or chittacks, as the old seer is divided, fifteen of these could therefore, with sufficient exactness, be regarded as equivalent to the present British Indian seer.

It has been pointed out by the Calcutta Committee that it would be possible to adjust the weight of the rupee so as to make it exactly commensurable with such a new unit of weight. The rupee weighs 11 66381 grammes, of which $\frac{1}{12}$th part, or 0 97115 grammes, is alloy (copper) By adding to the alloy 0 83619 grammes, the weight of the rupee would become 12½ grammes, or 80 would still go to the new unit of weight. Perhaps this proportion of alloy, about 17 per cent, or rather more than $\frac{1}{6}$th of the pure silver, might be thought objectionable, but it would at all events be easy to increase the weight to 12 grammes if it was thought worth while to have the rupee an exact number of grammes.

I have purposely proposed to take the kilogramme as the unit of weight in preference to the gramme The latter is, I think, generally admitted to be inconveniently small But the distinction between taking a unit and sub-dividing it into 1,000 parts, and taking the thousandth part of that weight as the unit and multiplying it decimally, is not one of much ultimate importance

And here I would observe that, while advocating the adoption of the French standard of weight, and looking forward to the future introduction of the decimal system of sub-division, I yet feel assured that it is not expedient to attempt to carry out the latter part of the arrangement at first, at all events in the ordinary dealings of the people.

In considering what course it is best to adopt in making a change in

the system of weights in India, it will be useful to bear in mind what was the actual course of events in France in the progress of the introduction of the metrical system there The new weights and measures were first adopted in 1793, but it was found very difficult to get them taken into common use, and the compulsory carrying out of the change did not in fact take effect till 1840 The time fixed in the original law of the National Convention in 1793 for the introduction of the new weights and measures was successively extended at various intervals, and in 1812 a decree of Napoleon legalized for retail trade a bastard system called the "Système Usuel," which retained most of the old weights and measures in their main characteristics, but assigned to them new values based on the units of weight and length of the "Système Mètrique" For other transactions the decimal system was retained. But much inconvenience arose from both systems having been legalized for retail business, and in 1816 the "Usuel" weights, &c, were made obligatory for retail trade, and the "Mètrique" for other business For retail trade the use of weights or measures decimally divided was absolutely prohibited In 1837 a law was passed, to take effect in 1840, by which the "Usuel" system was finally abolished, and the "Système mètrique" has since been in force for all transactions of every description in full integrity

The system of "Usuel" weight was as follows —

1 Livre = 500 grammes or $\frac{1}{2}$ kilogramme

This was sub-divided into 16 ounces, and these into various other parts on a binary or ternary system, thus ·—

1 Livre	=	16 Ounces	=	9216 Grains
1 Ounce	=	8 Gros	=	576 Grains
1 Gros	=	3 Deniers	=	72 Grains.
1 Denier	=	24 Grains		

Again, the lineal measures were the "Toise Usuel" equal to 2 metres, divided into 6 feet, and each of these into 12 inches, and further into lines, &c, on the old plan. The "Aune" was also preserved, being made 1·2 metre. The measures of capacity were similarly modified

I am disposed to think that even in a civilized country, the adoption of some such intermediate scale of weights between an existing system and a new one based upon a different unit which it is desired to introduce., is almost essential in order to habituate the people to the change of standard. This change having once been made, under cover of the

old denominations and systems of sub-division, the full introduction of a purely decimal system of multiples of the new unit becomes comparatively easy It is the duty of the Government, in making any change of the sort contemplated, to carry it out in the manner most likely to be convenient to the people of India, and having regard to their general extreme ignorance, it is I believe only by help of this artifice that the change could be brought about in a satisfactory manner

It will probably facilitate the complete apprehension of this proposal if I illustrate it by suggesting the sort of changes which its adoption would render necessary in the chief provinces of India.

In the first place, for Upper India, the kilogramme could be adopted as the new seer, with a sub-division into 16 chittacks, each of $62\frac{1}{2}$ grammes The chittack might be divided into 5 siccas of $12\frac{1}{2}$ grammes, or if the rupee weight were altered to $12\frac{1}{2}$ grammes, the name tola might still be retained instead of sicca For the purposes of ordinary trade no lower sub-division than the chittack would be needed. For goldsmiths and jewellers the gramme might probably be substituted for the *masha*, now $\frac{1}{12}$th of the tola, with a further sub-division into 10 *rutees*.

This seer would answer for all Bengal, for the North-Western Provinces, and probably for the Punjab and Central India.

The half-kilogramme would be nearly the seer of Guzerat

A maund of 40 such seers would be suitable for Bengal and Northern India, 25 maunds going to the ton of 1,000 kilos , and a maund of 20 such seers, for Guzerat and Malwa, 50 going to the ton of 1,000 kilos For the town of Madras, the viss might become $1\frac{1}{4}$ of a kilogramme , the Madras small seer would then be $\frac{1}{4}$ of a kilo , and the maund 10 kilos , the candy 200 kilos , 5 candies going to the ton Or the maund might be made to agree with the Bombay maund of $12\frac{1}{2}$ kilos.; in which case the viss would be $1\frac{9}{16}$ kilos , the seer $\frac{5}{61}$ kilo , and the candy 250 kilos , 4 going to the ton.

The Bombay maund might be taken to be $12\frac{1}{2}$ kilos, unless it were made 10 kilos , so as to assimilate it to the half of the maund of Guzerat, and the quarter of the maund of Northern India

Thus everywhere the kilogramme would be found at the base of the modified system of weights, and a definite proportion would be created between the old denominations and the new unit. When the people had become habituated to the change, the old names could be dropped, and

the elementary new unit would, without difficulty, become the general standard

It would, of course, be expedient to reduce the number of local weights as much as possible, and, so far as it could be done, to make the local weights of different provinces exact multiples or sub-multiples of one another, and if practicable, decimal multiples or fractions of the kilogramme The relation between the various local seers and maunds could perhaps be indicated by some suitable modification of the local names. For example, the maund of Bengal of 40 kilos might be called simply *mun*, the maund of Guzerat of 20 kilos, *mun-adhelee* (i e, maund halved), and the maund of Madras of 10 kilos, *mun-powah* (i e., maund quartered). Instead of these Hindoostanee affixes, it would be easy to substitute similar terms in the local vernacular language It must be understood that the suggestions I have above made as to the modification of the existing local weights are only intended to illustrate my proposal, and not to show exactly the best local systems The determination of the precise denominations of weights to be adopted in the provisional systems must be left for future careful consideration, as also the local limits within which each such system would be applicable

Following the course indicated by the history of the introduction of the new weights and measures in France, I should also think that it would be expedient to make the use of the complete decimal system based on the new unit obligatory from the outset on all Government establishments, on all Railways, on all Joint Stock Companies, and in all wholesale transactions in the chief towns or sea-ports The use of the new local weights would be made obligatory in all retail transactions in the chief towns, and beyond those towns in all transactions, excepting those of the Government, the Railway, and other large Companies

These suggestions, if adopted, would lead to the declaration by a law, applicable to all India, that the kilogramme, under some name to be specially chosen, should henceforth be the standard of weight.

That, for all Government establishments, and for all Railways and Joint Stock Companies, and in all wholesale transactions in the chief towns to be named in the law, the decimal multiples and sub-multiples only should be used, the necessary provision being made for assigning suitable names to such multiple and sub-multiple weights.

That, for all retail transactions, and for all transactions not above pro-

vided for, new local weights should be introduced, to be fixed as follows —

That the principal old denominations of weights should be retained, but that new values should be assigned to them, so as to make them, as nearly as possible, either exactly equal to the kilogramme, or exact decimal multiples or sub-multiples of it That in the descending scale a binary, or, if thought desirable, a ternary, sub-division might be followed

That the determination of the exact denominations of new weights to be adopted should be left to the Local Governments, as also the definition of the districts to which the new local weights should apply A general power of revision would be reserved to the Government of India, with the intention of harmonizing the various local systems and weights with one another, and of reducing the number of distinct weights as much as possible.

The only exception that appears likely to be necessary to such a general scheme as the above, is in the case of the dispensing of medicines, for which I presume that the existing English Apothecaries' weights must be tolerated so long as they remain in ordinary use in England. But the exception is not one of any practical moment.

I purposely avoid any discussion as to the precise names to be given to the new weights. Whether the French names should be used, or whether Oriental names should be given on a similar principle, are questions of detail. I am inclined to think, however, that old Indian names should not be given to any of the new denominations of weights which would form a portion of the permanent system, and that these old Indian names should be regarded as destined to be eventually entirely extinguished, when the use of the new scale had become sufficiently familiar to the people They would remain as a scaffolding on which the new system was supported on its first introduction, to be removed when that system was capable of standing by itself.

I also defer, to a later part of this Memorandum, the consideration of the time and manner of giving effect to the changes suggested. These points will be more conveniently dealt with after having discussed the other new standards to be adopted.

I now proceed to the standard of length. For reasons analogous to those already given in relation to the weights of India, I conclude that if any present attempt be made to introduce a new uniform unit, the metre will

be the best standard of length to adopt. But, as I have beforesaid, the expediency of taking such a step in the case of measures rests on different grounds from those which support the argument in relation to weights, and each must be judged on its own merits What these merits are may better be appreciated, as regards the standard of length, after the perusal of the suggestions which I shall proceed to offer on this part of the subject.

It is sufficiently notorious that all existing Indian ideas in relation to distances are extremely vague, and even the estimation of length in matters of retail trade is very lax It must have occurred to most people having even a moderate experience of India to see cloths measured by the forearm of the seller. The metre of 39·37 inches, and the half-metre of 18 68 inches, will be perfectly good substitutes for the guz and hath. As to distances, the necessity for an exact standard is practically only felt in occupations having some relation to European civilization, and in these the English mile and yard are of course the present accepted units Now, it so happens that the relation between the metre and the yard is such as to render the transition from English to French measures of length remarkably easy, at least within the practical amount of accuracy required for the ordinary concerns of life

The metre is 1·09363 yards. This differs from $1\frac{1}{10}$ yards by very little more than $\frac{1}{2}$ per cent. of the entire length, or $\frac{1}{6}$th part of an inch. Now, a mile being 1,760 yards, is 1,600 times 1 1 yards, and therefore differs very little from 1,600 metres. An illustration may be given of the practical effect of considering the mile to be 1,600 metres. The exact difference between them is 10 19 yards. This, on such a distance as that by Railway from Calcutta to Delhi, 1,020 miles, only involves a difference of about 6 miles If, therefore, for the present mile was henceforth substituted a mile of 1,600 metres, it would only lead to a difference of charge for the whole distance of nine annas for a first-class, and one-half an anna for a third-class passenger , this is about $1\frac{1}{2}$ pence in the pound.

The transition from a provisional mile of 1,600 metres to the kilometre and myriametre is obviously easy. The new mile could be divided into 16 parts, each of which would be 100 metres. Two and a half such miles would be 4,000 metres or 4 kilometres; a good approximation to the coss of the Moghul Emperors.

For retail trade in Northern India, the metre or guz might be divided, as at present, into 16 parts, called *girahs*, and into 24 parts called tus-

soos Each girah would be divided into 3 *anguls*, and each tussoo into 2 anguls

If in any part of India the use of feet and inches has become so habitual that their recognition would be desirable for the convenience of the people, there would be no objection to dividing the metre into 3 parts, and each of these again into 12, to take the places of the foot and inch.

With the exception of the Calcutta Committee, all the authorities consulted agree in advocating the adoption of the English yard or foot as the new standard of length I do not at all conceal from myself that very strong opposition may be expected to the adoption of the French standard of length, which would not arise in the case of the standard of weight. Practically, the English in India have been forced to accept more or less completely the native systems of weight But as regards measures of length, this has not at all happened The truth rather lies the other way , the English foot and inch being very generally known in all parts of India, and even being in common use in many trades The English yard is also widely used as a measure for woven fabrics

It cannot be denied, then, that the adoption of the English foot as a general standard of length, with a guz of 3 feet, would be much easier and more popular, both with the European and Native communities, than what I have advocated Also I admit that my proposal rests on what may, to some extent, be termed theoretical considerations of symmetry, as opposed to these which are practical. But I have so firm a conviction that the French unit of length will eventually be adopted generally, that I should not hesitate to fix it as the new standard for India, if it were determined to introduce one uniform standard, and if the decision rested entirely with myself as to what the new unit should be.

The really important point is, whether a uniform standard of length can now in any sense be said to be so necessary or so desirable as to call for present action. On this I cannot say that I have strong convictions, and I am ready to acquiesce in the conclusion that action should be deferred till some future time, if opinion be generally expressed in that sense I am, however, inclined to think that the change, as I have suggested it, might be made without any present inconvenience of importance. But I should distinctly object to the general introduction by authority of the foot as a standard, because I believe it would eventually have to be given up.

If the metre were adopted as the new unit, the only exception that seems necessary in introducing the change is in the case of English mechanical engineering, in which it is probable that for the present, at least, the English foot and inch must be permitted. Otherwise, the same general rules might be adopted with reference to the new standard of length as those which have been proposed in regard to the standard of weight. For all purposes of retail trade, local measures, based on the metre, or sub-divisions of the metre, would be made to suit the existing customs of the people, the decimal sub-division of the metre being used under all other circumstances. The retention of a modified mile of 1,600 metres would probably be convenient as a transitional measure for all classes.

So far as any special solid or cubic measures were needed, they would naturally follow the standard of length. I doubt the existence of such a want in India, however, unless in ship measurement, for which some special definition of a ton might be desirable. The English ship-builder's ton of displacement is 35 cubic feet, and therefore very nearly (0.991) a cubic metre. It is approximately the quantity of sea water which weighs 1 ton. The ton of measurement of 100 cubic feet is a purely arbitrary standard, for which might quite readily be substituted the cubic metre also.

The next subject for consideration is the standard of superficial measure. Of course this must follow the standard of length, and all that is here needed is to show what would be the probable practical result of the adoption of the metre unit.

In the same way that the mile is an exact multiple of 1.1 yards, it curiously happens that the acre is an exact multiple of a square having a side of 1.1 yards, being 4,840 square yards, or 4,000 times 1.21 square yards. Therefore, an English acre does not differ greatly from 4,000 square metres, or 40 ares of the French scale, and $2\frac{1}{2}$ acres is nearly 1 hectare or 100 ares.

The exact difference between 1 acre and 4,000 square metres is 55.87 square yards, which is about 1·15 per cent, the acre being the smaller. For all the ordinary purposes of life, such a difference is inappreciable. Few fields are more than 10 acres, so that in any single field the adoption of an acre of 4,000 square metres would not involve a change of more than $\frac{1}{10}$th of an acre, or one chain in the nominal area. Such an error would lead to an error of say $1\frac{3}{4}$ annas, on a payment of rent, or land

revenue, amounting to 10 rupees, or $2\frac{1}{2}$ pence in the pound Looking to the larger holdings of land, a village will not often be more than 500 acres, and on such an area the difference would only be $5\frac{3}{4}$ acres It is not to be understood, when I speak thus, that I mean to imply that the old measures are arbitrarily to be converted into the new ones. Naturally, a proper allowance would have to be made, to the extent of about 1 per cent, in all reckonings of areas, rent, &c., but the practical inconvenience and liability to loss consequent on such a change in ordinary transactions would evidently be very small

In the North of India the ordinary sub-division of land measures is by twentieths, *biswahs* and *biswansees* This at once suits itself to the adoption of a decimal scale of sub-division of the modified acre The biswah being the twentieth part of the acre, would be 200 square metres, and the biswansee, the twentieth part of the biswah, becomes 10 square metres The Madras sub-division of land measure is in fortieths, which is quite similar in its adaptability to the division of the acre of 4,000 square metres

If the metre unit were adopted, then the best practical course to pursue in regard to the land measures would probably be to take the square metre as the ultimate unit, but by way of transition, to keep an acre of 4,000 square metres, divided into four parts (decares) for Government purposes, below which decimal sub-division would be followed For the people their customary division into twentieths or fortieths might be permitted.

So far as *beegahs*, *cottahs*, *cawnies*, *valies*, or other local denominations of area were to be retained, they should be declared to be equivalent to a given definite number of square metres, taking, if possible, decimal multiples

On this part of the subject I need further only add that from considerations such as have already been sufficiently explained, I should not be disposed to assent to any change in the land measures of India short of the general introduction of the square metre as the unit But if, for any reason, this complete step be not taken, it will, I think, be very desirable that the Government, *for its own purposes*, shall everywhere adopt the English acre as the standard of land measure, and very strictly prohibit the use of, or reference to, beegahs or other local measures in all public documents The confusion now arising from the use of the term beegah, when it in fact means all sorts of areas, from 2 acres to $\frac{1}{4}$ of an acre, is beyond bearing.

The measures of capacity alone remain to be noticed. The French litre

is within an extremely small fraction, which practically may be neglected the thousandth part of a cubic metre. It is the volume of one kilogramme of pure water of maximum density and at the standard barometric pressure. If this unit be accepted, it will naturally fall in with the *kilogramme* as a standard of weight.

As to dry measures, it may be easy to adjust a measure which holds *exactly* one kilogramme of pure water, so as to serve also as a measure for one kilogramme of grain, which is the chief article sold by measure. The weight of a given volume of grain is about $\frac{8}{10}$ths only of the same volume of water. If, therefore, the litre were filled with grain and the measure "struck," the weight contained would only be $\frac{8}{10}$ths of a kilogramme. But by "heaping" the grain, it will, of course, be possible to add to the capacity of the measure. What would be necessary, therefore, would be to adjust the relative depth and diameter of the litre for grain measurement, in such a way as to make the "heaped" portion which stands above the true surface of the measure compensate for the inferior weight of the grain as compared to water. I reckon approximately, that to make this adjustment the height of the measure should be about $\frac{2}{3}$rds of the diameter. But the exact proportions could be regulated by law in accordance with the result of actual experiment.

Mr Bayley has proposed to follow the English system of recognizing only "struck" measure. But if, as he says, the people always use "heaped" measure, it seems better to follow the present custom as regards the sale of grain at least, and, so far as I can see, the accuracy of the measurement will be quite sufficiently secured in the manner suggested, without abandoning the precise standard dimensions of the measure, a result which cannot be accomplished in any other way.

In respect to fluid measures, the litre which contains 61.0266 cubic inches, is about $\frac{1}{18}$th more than the old wine quart, which contains 57.75 cubic inches. It is equal to .220215 imperial gallons, and about $\frac{1}{8}$th less than the imperial quart of 69.281 cubic inches. The hogshead of 54 old beer gallons contains nearly 55 imperial gallons, and differs from 250 litres or $2\frac{1}{2}$ hectolitres, by a trifle less than an imperial pint, or hardly more than $\frac{1}{6}$th per cent. It is probable that for ordinary purposes, in the conversion of English fluid measures into the new standard, the litre might be assumed as equivalent to the wine quart, and the beer hogshead as equal to 250 litres.

The same general system might be followed in the introduction of new measures of capacity as of the other new standards. The retail and country dealers might have special local measures assigned to them commensurable with the litre, but adapted to the existing local measures. The wholesale dealers in the chief towns, and the Government establishments, might be restricted to the decimal system based on the litre.

As to the general question of the necessity for dealing with measures of capacity at present, it may be said that if the introduction of new standard weights be determined on, then new fixed measures of capacity for grain or other dry goods, conformable to the new weights, will be essential for the convenience of the people. This being the case, it will, in the event supposed, be at least as convenient to adopt the litre as the unit for dry measures, as any other standard. For liquids, the necessity for any measures hardly arises as regards the mass of the people. With reference to the English community, although a change to French measures would perhaps be distasteful at first, there is little doubt that, for the purposes of ordinary life, they would, in a very short time, be universally found and admitted to be actually more convenient than the English Imperial measures, which in fact are not in common use. If such a view were generally accepted, the litre might be taken as the new standard of capacity for India. Otherwise, I should consider that the proper course to follow would be to deal exclusively with the dry measure in the manner that has been suggested.

No CCXXXVI

THE ROORKEE FOUNDRY AND WORKSHOPS.

The Canal Foundry and Workshops at Roorkee, of which a plan and perspective view are given in this Number, belong to Government. The Workshops were first erected in 1843, in connection with the works then in progress on the Ganges Canal, and were then, and till 1852, part of that division of the Canal which included the Solani Aqueduct and the heavy works in its vicinity. In November 1852, the Workshops were separated from the Canal, under the same management but with an extended charter. They were to manufacture work for both the Government and for private parties, and to be self supporting. From the commencement of their independence, till March 1864, a period of 11½ years, the Workshops progressed in size and in capacity for executing work, but their financial condition was neglected, and the consequence was that, in the above period, a loss of Rs. 4,24,455 was sustained, and this without allowing anything for the use of the capital, which the State provided From March, 1864, to the present time, the concern has been very remunerative to the State; the value of work turned out and the profit on it have steadily increased, while the price of the articles manufactured has decreased The statement on the next page will show clearly the progress that has been made.

The Workshops contain a Turning shop worked by a 20 H. P. Engine—a Foundry with a 12 H. P. Engine,—a Smiths-shop with two Steam Hammers,—and a scrap Furnace for wood fuel,—a Fitting and Boiler making shop with a steam rivetter,—a Pattern shop—a Carpenters' shop with Saw-mills driven by a 10 H P. Engine; the Carpenters' shop contains a variety of wood working Machines, lastly, a Mathematical Instrument shop, where Surveying Instruments are made and repaired.

The range of work executed is very great in a country like this, an establishment of this kind to be generally useful must undertake almost

Period.	Value of work executed	Value of capital	Net profit	Percentage of profit on capital per annum
1st March 1864 to 30th April 1865, 14 months,	3,75,282	10,82,845	63 166	5
*1st May 1865 to 1st May 1866, 12 months,	2,80,523	9,73,083	29,270	3
1st May 1866 to 1st April 1867, 11 months,	3,28,818	9,53,544	60 199	6
1st April 1867 to 1st April 1868, 12 months,	3,82,441	11,08,371	1,00,173	9
1st April 1868 to 1st April 1869, 12 months,	4,76,041	11,78 416	1,28,909	11

any kind of work, amongst the work executed, are steam engines of all kinds from Locomotive to Stationary,—all kinds of Bridge and Girder work,—Pumps, Printing presses, Hydraulic Presses, Machinery such as Planing, Slotting and Drilling, Lathes of all kinds, Levels, Prismatic and Surveying Compasses, Scales, Mathematical Instruments, and Scientific apparatus in general.

The benefit that these Workshops have been to the country, in training workmen and introducing a better and higher style of work, has also been very great.

The work executed goes all over India, the quality is better than can be got elsewhere in India, and equal to that of first class English Houses.

The average number of workmen employed in connection with the Shops are—

	ARTIZANS			LABORERS		TOTAL		
	Mussulmans	Hindoos	Christians	Mussulmans	Hindoos	Mussulmans	Hindoos	Christians
Turning shop, ...	20	16	..	18	12	38	28	..
Foundry, ...	10	49	.	4	35	14	84	..
Smithy, ...	5	43	..	4	3	9	46	..
Fitting shop, ...	85	98	1	13	10	98	180	1
Pattern shop, ...	..	25	.	1	2	1	27	..
Carpenters shop and Saw mills,	7	36	..	21	25	28	61	..
Mathematical Instrument Department,	14	10	..	4	1	18	11	..
Store Department, ...	..	..	..	12	7	12	7	..
Despatching Department, ..	..			1	9	1	9	..
Cargo Boats, ...	.	..	..	15	118	15	118	..
Counting Department, ...	..	..	..	..	6	.	6	..
Cutting Firewood and making Charcoal,	.			50	280	50	280	..
	141	277	1	143	508	284	785	1
Total number of men employed, ..								1070

* The unfavorable results of this year are due to the closing of the Forests by the Government, rendering it difficult to get fuel and thence increasing the cost of production greatly.

CANAL FOUNDRY AND WORKSHOPS, ROORKEE

PLAN

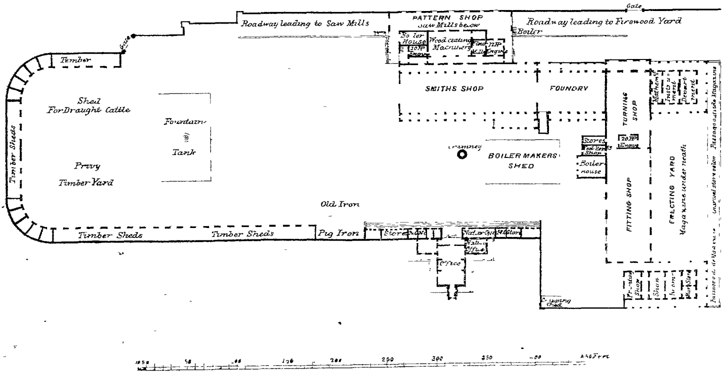


PLATE XXIV

This is exclusive of supervising establishment The wages of the mis-trees or foremen of each shop, vary from 100 rupees to 25 per month. The wages of the artizans vary greatly they are paid the highest in the Mathematical Instrument Department, the wages varying from 1 rupee 4 annas per day to 4 annas In the other departments, the pay varies from 8 annas per day to 3½ Of the workmen, the Mussulmen are the most active and intelligent This does not arise from their abilities being better then the Hindoos, but they seem to have more ambition, and more power of command over the others With the exception of the Turning shop, all the foremen are natives The enginemen and stokers are all natives Some of the men are very good and quick workers, but the general run of them are inferior, the great difficulty is to get them to understand the necessity for accuracy, and to use their eyes, but this is not to be wondered at, in native houses you never see anything put up square and straight to the eye, and articles made for native use are simple, and a rough approximation to correctness is all that is required

The amount of work done for Government and for private parties, during some years, have been about half and half, but the general average may be taken at ⅔rds Government and ⅓rd private

Natives come from all quarters to view the shops, and are loud in their praise of everything, but their great delight is to see castings made, the melting of iron being something that they never have seen done. They are always sceptical about it till they really see it running out of the furnaces. The Nawabs and Rajahs of the North-West have, in several instances, erected workshops and machinery from having seen what can be done at Roorkee.

When once the natives become intelligent enough to use machinery in their agricultural operations, the demand for thrashing, shearing, winnowing machines, and other agricultural implements, will be great, and the Roorkee Workshops, by training men to fit up such machines, and repair them when broken, are doing a great service to the country.

A. C.

No CCXXXVII.

THE NERBUDDA VIADUCT—BOMBAY AND BARODA RAILWAY

No CCIV of these papers gave an account of the damage done to the above structure by the monsoon floods of 1867, and of the measures taken to remedy them

The floods of the following year, 1868, resulted in three of the piers being carried away in the deepest part of the stream, and the Consulting Engineer to Government (Lieut.-Colonel Trevor, R E,) in reporting the accident, submitted the following history of the Bridge from its commencement. For *Plates* see the former paper

Account of the Nerbudda Bridge, since its commencement in 1858, *with remarks as to the observed effect of floods on the Mhye Bridge, and the changes made from time to time in the design*

THE first design for the Nerbudda Bridge provided for 44 spans of 60 feet over the main stream, and for 15 spans over the southern branch known as the Blind River. The height of the bridge was determined by a reference to a former flood, of whose height a record had been kept by a mark on the Government Custom House in Broach, supposed to be the highest flood known This flood rose to 44 feet above low-water-mark spring-tides. In the bridge design, the bed-plate of the standards supporting the girders was placed three feet above that level.

During the working season of 1857-58, the bank between the Nerbudda and Blind river, as well as the bank between the Blind river and the high ground at Soorwaree were formed. In the monsoon of 1858, a flood occurred, which rose to within 1½ feet of the highest recorded flood. At the main channel, 300 yards of the new bank were washed away, and the sand, on which it had been thrown up, was scoured out to a depth of 4 or

5 feet At the Blind river, 120 yards of the bank were eaten away by a current which ran from the main stream along the railway bank into it Two openings that had been left in the bank between the channels of the Nerbudda, for the construction of bridges intended to serve as road crossings, were enlarged by about 100 yards

These disasters led to a re-examination of the plan in which the waterway proposed for the river was divided, and after sections had been made of the river, both up and down stream, it was finally decided to confine the river to one channel, to enlarge the bridge over the main stream from 44 to 60 feet, and to dispense with a bridge at the Blind river, and close all the openings between the Blind river and the main stream left for roads crossings.

The proposed alteration in plan having been approved by Government, the construction of the bridge commenced in October 1858, and 17 spans on the northern bank were erected before the monsoon of 1859 In the season of 1859-60, changes were made in the engineering staff, the staging was more than once carried away by high tides, cholera broke out among the workmen, and from these causes and others, no great progress was made with the bridge till late in the season, but by July, 41 piles were fully screwed, and 28 partly screwed, on the south bank, which is dry at low water, and a few were put in further out in the stream During a flood which occurred in the monsoon of 1860, and rose 25 feet above low-water spring-tides, the timber staging which had been left in on the south bank was most of it washed away A detached pier No. 23, from the north bank, which was braced and erected to within two lengths of its full height, was washed over, and an unhealthy vibration was observed in the down stream and strut piles of the 17 spans already completed on the north bank

In the season of 1860-61 great exertions were made to complete the bridge, and in July 1861 it was opened for traffic

In the design originally proposed for the bridge, the piers consisted of three upright cast-iron piles $2\frac{1}{2}$ feet in diameter, and one strut pile of the same dimensions placed obliquely on the down stream side of the structure. Mr. Forde, the first Chief Engineer, added on to each pier he built a fender pile on the up-stream side similar to the strut piles on the down stream side of the piers, but his successor, Mr Sanderson, considered these up-stream fenders useless and unnecessary, and with the concur-

rence of the Company's Consulting Engineer, substituted timber fender piles in their place, after a design furnished by the latter

The bridge, though opened in 1861, was not then fully completed, and work has never been actually stopped on it till the present day. The roadway girders were erected on the up-stream side only, the down-stream piles being tied together with rod iron, and in order to overcome difficulties in screwing, where the debris of piles broken during the construction of the work was embedded in the sand, two makeshift girders of 90 feet span had, with a view to change the position of the piers, been put up in the deepest part of the stream, instead of three 60 feet girders. These two 90 feet spans were separated by six spans of 60 feet The work done during 1861-62, 1862-63, and 1863-64, consisted principally in completing the piers according to Mr Sanderson's plan, putting in bracings, recovering lost piles, &c As objections had been raised to the 90 feet spans, it was decided to convert each into two spans of 45 feet, and piers were with this object erected in the middle of each, but were, not connected with the superstructure.

In 1864, Colonel Pitt Kennedy, the Company's Consulting Engineer, who was then in India, became convinced that up-stream fender piles of cast iron, as previously applied by Mr Forde, and the erection of the second line of girders, were necessary to ensure the stability of the bridge, and estimates were prepared for these additions, but in the monsoon of 1864, the river, which had been free from any floods of consequence since 1858, again rose to about 31 feet above low water mark, or within 13 feet of the known highest flood level, inundating the country between Soorwaree and the Nerbudda Six spans of the Nerbudda bridge were carried away and a girder bridge of 60-feet span in the bank, between Soorwaree and the Blind river, fell in owing to the undermining of the abutment.

Mr Mathew, then Chief Engineer, observed as follows, in his report of the 3rd August 1864, with reference to the Nerbudda Bridge —

"We found that the six spans as marked in the diagram herewith, had disappeared, and that several cluster piles and fenders were broken. From the manner in which the struts and fenders were broken, it was apparent that the breakage was by concussion of large timbers brought down by an extraordinary flood. On going over the bridge, we found the structure, although the flood was still running with considerable

velocity, perfectly steady, except close to the break where the strut piles were broken or wanting, but, on the south side of the break, the longitudinal tie on the third row of piles had given way, and the columns weighted to the top with concrete, and caps, oscillated in a manner likely at any time to result in fracture."

In the same report, in summing up his conclusions as to the cause of all the accidents that occurred during the flood of July 1864, to the bridges in Goozerat, Mr Mathew observed :—

"From the particulars above given, it will be apparent that the accident in each case to the iron pile piers, and to the timber fenders, when erected, is attributable to the same cause In no case has a vertical pile been broken where it has been defended by an up-stream strut, but, in several cases, the timber fenders have been broken both on vertical and in strut piles I am now, on the whole, of opinion that up-stream strut piles should be put on every pier of the Mhye, the Nerbudda, the Taptee, the Watruck, the Veturnee, and both up and down stream struts at Bassein, and that more substantial covering or fenders than heretofore adopted should be put on every pile exposed to similar injury in this and other rivers I also propose to put a more substantial tie along the third row of piles in absence of the double superstructure"

At this time it would appear that it was Mr. Mathew's opinion that the injury to the Nerbudda was caused entirely by floating timber, though he recognised the danger arising from the oscillation of vertical piles which were imperfectly secured.

In a subsequent report, dated 3rd September 1864, Mr Mathew described the effects produced by a second flood in the Mhye river. In the former flood, which occurred nearly at the same time with the flood which injured the Nerbudda bridge, the Mhye bridge had been described as firm as a rock—four strut piles only had been broken by blows (as it was supposed) of floating timber, but in the second flood, which rose higher than the first, Mr. Mathew found the condition of the bridge very different, he observes —

"After the first flood the bracing was intact, the bolts throughout required very little tightening, and four up-stream struts only had been broken, where as after the last, the longitudinal ties throughout the bridge were slack, so as to admit of considerable movement in the piers, the pile bolts throughout had worked loose, and as a result, nine strut piles had

fallen away, and two in falling had slightly fractured the vertical piles."

"On the down stream side, where the piles are unweighted by superstructure, the third row with the struts attached oscillated to a considerable extent, and the joint bolts having worked loose, the columns weighted to the top, in falling over, broke away the joint bolts. The up-stream struts were similarly affected, but not to the same extent, as the movement on them was due only to the action of the flood, the vertical piles to which they were attached being under the superstructure

"As regards the up-stream struts, I concur in Mr Richmond's opinion that they were broken by concussion from large timber, as the observed motion in them during the flood, and the after condition of them was not such as to account for failure in the manner in which the down-stream struts fell away. The struts on both sides being over 20 feet at base from the vertical columns, there is considerable difficulty in bracing them so as to prevent the movement described in them, and the bracing at present is not at all adequate "

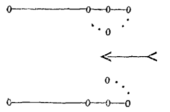
Mr. Mathew observed a little further on in his report, after commenting on the dangerous effects of a vertical pile breaking, that—

"Looking to the manner in which the structure is braced throughout, it is to be apprehended that if a pile under the superstructure had fallen away, the greater part of the superstructure would have followed it into the river"

It would appear that after experience of the second Mhye flood, Mr. Mathew recognised more fully than before the extreme danger arising from the motion of detached piles, the weakness of the pile joints, and the dependence of the bridge for stability on the integrity of each pier.

The remedies recommended at the Nerbudda were—filling in the smaller openings between Soorwaree and the Blind river, strengthening the horizontal bracing between the piles of each pier by substituting double bracings of T iron between the outside lugs of the pile for the single bracing between the centre lugs, placing a substantial tie along the down stream detached piles in the absence of the double superstructure, and a more substantial fender on the up-stream piles, and adopting a suggestion made by Colonel Pitt Kennedy, of putting in a fourth pile in each

pier as shown in margin. In his report recommending this last addition, Mr. Mathew observed that "the stability of the piers in the direction of stream and transverse to the bridge is already ample when the piers have been completed with struts and fenders," and expressed the opinion that the additions proposed would be sufficient "to render the bridges perfectly secure" The same measures were recommended for the Mhye bridge, with the addition of horizontal diagonal ties from pile cap to pile cap



Government, after some discussion, sanctioned the re-erection of the six spans of the Nerbudda on the old design as a temporary arrangement, and they also sanctioned the strengthening of the bracing, the erection of the second lines of superstructure, the additional horizontal ties with screw-shackles, and wooden fender piles, but they did not approve of the addition of a fourth vertical pile in each pier, and they addressed the Secretary of State in April 1865, with a view to induce the London Board to adopt measures for re-building the bridge on a better design.

The six spans of the Nerbudda bridge were completed at the end of April 1865. Of the 15 vertical piles carried away, 5 had been found broken above the surface, and were simply remounted the rest had been broken below the surface, or covered up by silt, and the fracture took place in some cases in the screw or lowest joint, which had to be extracted at great labor and expense. The following extract from a report by Captain Hancock, dated 22nd March 1865, refers to the state in which the broken piles at the Mhye and Nerbudda were found He remarks—

"I had an opportunity of looking at some of the fractured piles both here (*i. e.* at the Mhye) and at the Nerbudda. They had not broken, as I rather expected to find, at the bolts, but, generally speaking, right across the cast iron cylinder. In one case a pile was taken out with four feet of the screw joint attached to it, the rest of the screw joint being broken off in the ground. In another, a pile under the roadway was broken across near the middle, a gap of about an inch appearing between the pieces, and the pile only standing at all because held in position by the concrete pillar inside Generally, the wrought iron bolts seem to

have been sound, and to have held well, and the joints to have been stronger than the rest of the pile The Engineers are, I think, agreed now that it was the violent vibration that snapped the piles across, and not, *as a rule*, blows from the timber or other piles falling. In fact the position of the fracture, often close to or below the ground, showed that blows were not the immediate cause of failure in these instances "

By the middle of July 1865, the second line of girders had been put up throughout the deep water channel of the Nerbudda, except across the two 90-feet spans, on which substantial bracings were reported to have been constructed.

In July 1865, a flood, considerably lower than the flood of 1864, rising 22 feet above low water mark, came down the Nerbudda The bridge was supposed to be stronger than it had yet been, but although the flood was only some 7 or 8 feet above high water mark spring tides, and the calculated mean velocity was only 10 miles an hour, an unhealthy movement was observed in some of the up and down stream piles, and some of the bracings were found to have broken between low water mark and the bed of the river. These bracings were reported to be of inferior iron, and the movement in the piles was attributed to the failure of this bracing

It may, however, be doubted whether this was not substituting cause for effect. The bracings would hardly have given way except under strains caused by vibration.

During the same flood, the remaining pier in the middle of the second ninety foot span was washed over, as the fellow pier to it had been in 1864. Besides the bracings broken or twisted, many pile bolts worked loose, and collars were twisted.

In reporting on the dangerous condition of the Nerbudda bridge on this occasion, Mr. Mathew recommended the following alteration in design :—

1st. The up and down stream fender and strut oblique piles to be exchanged for vertical piles taken up to the full height of the bridge.

2nd. A continuous girder to be put up over the heads of the five piles, strong enough to bear the girders in case of the failure of any one pile.

3rd. To form clusters of 11 vertical piles at every 6th pier.

It was suggested afterwards that each up-stream pile should be furnished with a floating breakwater to rise and fall with the stream, as well as a teak baulk strapped on to it. A suggestion of Colonel Pitt

Kennedy, to place detached clusters of pier piles with floating timber fenders, up-stream of the cluster piers, was objected to by Mr. Mathew and the Government Engineers, as it was thought they would be liable to fall way and injure the piers they were intended to protect

The measures recommended by Mr Mathew were generally approved by Government on the recommendation of Colonel DeLisle, and were finally approved by Colonel Pitt Kennedy, the object of the cluster piers being, to quote Mr. Mathew's Report, to give "longitudinal stability to the bridges," and to prevent "the continuous movement which has been experienced in them"

Government had addressed the Secretary of State in September 1865, and recommended "that no further time should be lost in having measures taken to obtain such an opinion on the bridges as may lead to their being either effectually strengthened or re-placed by others of stronger and more durable construction, the present structures are already unsafe and not to be depended upon" and subsequently, when the details of the above proposals were submitted, Government had referred all the papers to the Secretary of State, and it was at first intended that the orders of the Home authorities should be awaited before work was commenced, but in January 1866, the Railway authorities represented that if orders to commence work were not soon given, the working season would be lost, and that it was dangerous to delay the strengthening of the piers, as several cracked piles had been discovered. Mr. Mathew, in his report of the 24th January 1866, especially urged the necessity for removing the strut piles, and completing the piers with 5 vertical piles and cross girders without delay, and quoted a letter from Colonel Pitt Kennedy, in which he stated that he concurred most fully in the general principles of the design recommended.

At the same time, Mr Mathew represented that the floating breakwater which had been proposed for the up-stream fender piles would not answer, and proposed instead to cover all the up-stream piles with fenders of solid teak, not less than 24 inches on face He also again called attention to the facility with which cartways might be added to the bridges when the piers were altered as proposed, a point which he had referred to in his first report

The measures proposed were, for these reasons, partially sanctioned by Government in Februrary 1866, in anticipation of orders from England,

and detailed estimates were submitted and finally approved by the Government of India. The work was at once commenced, and considerable progress made in the screwing of the additional vertical piles that season The double line of superstructure had been previously completed throughout the Mhye and Nerbudda

The monsoon of 1866 passed without any heavy floods, or any damage being done to the Nerbudda or Mhye bridges. The Secretary of State, with his despatch of the 9th August 1866, forwarded papers containing the views of the London Board on the proposals submitted. The Directors stated they had conferred with Mr Mathew, who was then in England, and with the Consulting Engineer, and "after the strong opinions expressed, both verbally and in writing, by those officers who have had the designing and carrying out the work connected with their bridges the Directors consider that there need be no apprehension as to the future stability of these structures, and trust that Government will agree in the expediency of their being more fully tested by time before any other measures are taken which would involve the Company in a considerable additional capital expenditure."

The Secretary of State so far agreed with the Directors as to consider that "the durability of the existing bridges as now strengthened should be fairly tested before any steps are taken towards replacing them by new structures" Accordingly the works already recommended were considered as finally approved and sanctioned, and orders were given that they should be carried out in full

The Company's Consulting Engineer, Colonel Pitt Kennedy, in letters of the 11th May 1866, and the 28th July 1866 (copies attached to the Secretary of State's Despatch), had said that the monsoon of 1866 would find the bridges provided with proper timber fenders to resist the drift wood brought down like a battering ram against the piers, and congratulated the Directors on the total exemption from failures from defective foundations or insufficiency of waterway, and Mr. Mathew expressed the opinion, in a Report of the 20th July 1866, that the bridges, when strengthened as proposed, would "be as secure and as permanent in character as any other iron bridge structures in similar positions in the world"

It should be added that Mr Mathew had suggested that, in order to make the piles stronger at the joints, the lengths should in future be cast

with socket joints, and that Colonel DeLisle had suggested that iron-toughened by an annealing process should be employed, as better calculated to resist blows of timber

During the working season of 1866-67 considerable progress was made with the screwing both of the additional vertical piles and of the piles for the cluster piers, the 24-inch timber fenders were placed up-stream in the Mhye and Nerbudda, and a good deal of the pier bracing doubled As the continuous cross girders which had been ordered from England had not arrived, it was arranged that all detached piles which could not be fully braced should be dismounted before the monsoon, but it was considered that where the double bracing had been applied, the detached piles might be left standing, the caps being, as a measure of precaution, braced very strongly longitudinally and crosswise, with rod iron, to prevent motion Many of the detached piles thus left standing in the Nerbudda Bridge were not concreted

In the monsoon of 1867, the Nerbudda rose higher than it had done since the bridge was constructed, but its reported rise was not within ten feet of the height of the flood on a calculation of which the bridge was built, nor was it many inches higher than the flood of 1858.

This flood of August 1867 destroyed most of the bridges left in the bank between Soorwaree and the Blind river, which Mr Mathew had recommended in 1864 should be filled in, but which had been left standing. The flood also carried away some 600 feet of the bank on the south of the main bridge The bridge itself was but slightly injured; but ten of the down stream detached vertical piles gave way at the joints, the cross bracings being broken, or the lugs of the pile torn away This was attributed to the bolts at the joints working loose, the piles being recently put up, and not being concreted. Two of the up-stream detached piles were also broken and seven detached and incomplete piles in two of the unfinished clusters; but these last were not braced, and were only erected to one-third of their height.

The comparative immunity of the up-stream detached piles from injury was attributed to the stout wooden fenders braced to them. A quantity of heavy timber came through the bridge on the afternoon of the 19th August, and every one was reported to have been struck several times

On the whole, the result of the test to which the bridge had been sub-

jected was considered favorable Mr. Mathew observed, in his report of the 29th August 1867, "The experience this season is, I submit, sufficient to prove that next season, when the transverse girders for pier tops, which are now on the way from England, have been put up, and when the cluster piers which are now incomplete have been erected, there will be little further to desire in this great structure"

The Mhye Bridge also stood well through a flood on the 14th September 1867, which was reported to have risen within three feet of the height attained by the flood of 1864 "Quantities of very heavy timber were brought down" (Mr Warren's Report of the 17th September, 1867), "some of the logs striking the booms, but doing them no injury The bridge was quite stiff, and, except in the tie rods, no motion was perceptible." Mr. Mathew, in commenting on this Report, observed in his letter of the 28th September 1867, "the only weak point in this bridge as now designed will be in the pile columns up and down stream Any iron longitudinal tie will admit of slight movement, which, as has been experienced at the Nerbudda, may cause the pile-bolts to work loose. To prevent this, I propose to put, upon the spare down-stream and side lugs of the piles, clamps with keys" Mr Mathew also alluded again to the cart-ways as likely to strengthen the bridge. An estimate for the steel pile-clamps proposed by Mr Mathew was sanctioned in October 1867 No further addition was suggested to the former design, but it was decided, after much discussion, to close all the small bridges in the embankment between Sooiwaree and the Blind river, and to add 12 spans to the bridge over the main channel, increasing the waterway to 4,380 feet.* Six of these spans had been put in before the floods came down in 1868, and the waterway at the main bridge was then 4,020 feet, but before entering on the subject of the floods of 1868, it will be well to recapitulate the alterations proposed in the original design, and the object of them, and to state how far the new work had progressed

I. The single horizontal bracing between the piles composing each single pier was to be replaced by double bracing strutted between the outside lugs of the piles. The object was to give greater transverse stiffness to the piers. The work had been carried out partially only, as a different kind of double bracing between the middle lugs had been, to save time, put in in some piers, but the double bracing from outside lugs had been

* *See* No. CCIV. of these papers.

fixed in the lower joints of nearly all the piles in the deep water channel of the Nerbudda

II. The up and down stream oblique piles were to be removed, and vertical piles substituted, connected at top with a continuous cross girder, and with a 24″ timber baulk up-stream.

The object was threefold —

1st —To remove a source of danger arising from oscillation of oblique piles of great length, without materially diminishing the transverse strength, of the piers

2nd.—To give a fender pile up-stream in place of the old oblique fender.

3rd —To increase the number of vertical supports for the superstructure, and render the bridge less dependent on the integrity of each single pile column.

The work had made great progress, the only part of it which was behind-hand, being the erection of the continuous girders, which arrived rather late in the season, several had, however, been put up in the deep channel of the Nerbudda, and the work was being continued.

III. The erection of cluster piles at every sixth pier.

The object of this was to prevent the continuous movements which had been experienced, and give longitudinal stability.

The work had made great progress, so far as the erection of the extra piles was concerned. Throughout the deep channel of the Nerbudda the cluster piers were, except as regards the upper work, complete.

The south end of the bridge had been secured by a temporary abutment of timber six spans had been added to it. as above stated.

It was generally believed that no apprehension need be felt of accident to the bridge arising from defects which the above works had been designed to remedy.

Some anxiety had, however, been occasioned by the discovery that some of the piles had not been screwed down to the solid sub-stratum of clay, but that, on the south bank especially, many only rested in sand and alluvial deposit. There had been considerable scour on the south bed in 1867, which it was feared might occur again. Orders had been given that, so soon as the continuous girders could be put up, the piles, which were supposed to be short, should be re-screwed one by one.

Such was the state of the Nerbudda Bridge, when, on the 10th August

1868, a heavy flood came down the river. This flood rose to within three feet of the flood of 1867, or within fourteen feet of the highest recorded flood. No injury of consequence was done to the embankment* on the south of the river, which had suffered so much in 1867 and in 1858, but three piers of the main bridge were carried away in the deepest part of the river. These piers were numbered 24, 25, and 26

Pier 24 was a single pile pier of 5 piles, the continuous cross girder had been erected on it, but some of the minor attachments were not complete.

Pier 25 was a cluster: all piles in, except No 5 down stream centre, pile. Piles all braced, but no cross girder put up.

Pier 26, under 90 feet span, consists of three vertical piles *only*, the upstream pile of the three not attached to the superstructure, but tied with rod iron to adjacent piers

This failure Mr Mathew attributes to the piles being under-scoured and not to the impact of heavy timber, of which it is reported that little came down the river The crash, however, occurred soon after midnight: the accident was not witnessed by any one, and it cannot be ascertained which of the piers first gave way, the cause is therefore mainly a matter of conjecture

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It will be seen from the above history of this structure that expenditure has been sanctioned from time to time for the following objects :—

I. To increase the waterway (12 extra spans at south end, sanctioned in 1867-68).

II. To maintain the strength of the piers in the direction of the stream, but at the same time to obviate danger from oscillation of the long oblique piles which formed part of the first design (extra vertical pile up and down stream in place of oblique piles)

III. To prevent piles from swaying transversely to the stream (double superstructure, longitudinal bracing from pile caps, continuous cross girders).

IV. To give lateral stiffness to the piers of single piles (double horizontal bracing, cross girders).

V. To prevent continuous movement transversely to the stream (cluster pile piers).

* All the openings had been closed.

VI. To render the superstructure less dependent for support on each single pile column (up and down stream vertical piles and cross girders).

VII. To save the piles from being broken by impact of heavy timber (up-stream vertical pile with 24-inch teak baulk strapped to it).

VIII. To render piles safe from action of scour (piles not down into clay to be rescrewed).

IX. To strengthen pile joints above ground (steel clamps for pile lugs),

I propose to consider how far these measures have been successful.

With regard to item No. I., I would point out that no calculation has been made from observed data of the flood discharge of the Nerbudda, nor have levels ever been taken to show the general slope of its bed. All that we can go upon, in determining the waterway to be given to the bridge, are general data, not confirmed by actual experiment. The drainage area of the Nerbudda is a little less than 40,000 square miles. Colonel Dickens drew out an empirical formula ($D = 825\ M^{\frac{3}{4}}$ where D is discharge in C. F. per second, M drainage area in square miles) to ascertain the maximum floods to which Indian rivers are subject, from some data he collected in Bengal. Calculated by this formula, the maximum discharge of the river would be under $2\frac{1}{2}$ million cubic feet per second.

According to the last section of the river, the average depth of water in it, under the existing bridge in the highest known flood, would be 45 feet nearly, and the maximum depth 69 feet. The present length of the bridge between abutments, including the six spans added in 1867-68, is 4,020 feet, from which has to be deducted the width of the ordinary, and cluster, piers, which give a total obstruction of about 316 feet. The clear waterway of the bridge may thus be put down at 3,700 lineal feet or say 166,500 superficial feet. Through an opening of this size the discharge of $2\frac{1}{2}$ million* cubic feet per second would be effected at a mean velocity of 15 feet per second, and a maximum surface velocity of about 22 or 23 feet a second, which, according to Ellet's formula for

* Calculated by Colonel Dickens's formula, the maximum discharge of the Taptee would be about $1\frac{1}{2}$ million cubic feet per second. Its actual maximum discharge, according to data, gathered by Colonel (then Captain) Chambers in 1860, is not more than one million cubic feet per second. The Taptee and Nerbudda are parallel rivers, not unlike in the configuration of their catchment basins or in the rainfall of the countries they drain, but the Taptee is the smaller of the two. The comparison between the computed and actual discharge of the Taptee shows, however, that the maximum discharge of the Nerbudda is likely to exceed $2\frac{1}{2}$ million cubic feet per second.

rivers, corresponds to a surface slope of 2·7 feet per mile. There is nothing in these figures to indicate the necessity of further enlarging the bridge, but they are a significant token of the dangers that attend the bridge, unless its foundations are well below the level within which scour is possible. Colonel DeLisle, I think, over-estimated the discharge, in consequence of assuming an excessive slope for the river-bed. My conclusion is that the work of screwing the piles to a safe foundation (No. VIII.) is far more important than adding the second six spans at the south end, and should certainly be proceeded with in preference.

With regard to items Nos. II., III., and IV in the above list, which it will be convenient to treat together, I would observe that the transverse strength of the piers of five vertical piles now substituted may also be admitted to be sufficient, though I doubt if *theoretically* they are as strong as the old piers, but it is hardly necessary to observe that by lengthening the piers, the strains in the direction of the length of the bridge, arising from oblique currents, have been increased. This would be of little consequence if the piers, as formed of single piles, had superfluous strength in the direction of the bridge; but this is the direction in which they have been shown to be weakest and most defective, by the frequent failure of piles not braced longitudinally, and the destruction of the detached piers put in for 45 feet spans year after year.

The old oblique piles, it is true, were a source of weakness from a similar cause, but they were attached to the vertical piles by long weak bracings, which, although they did not check movement in the oblique piles to any extent, had this one advantage, that they gave way easily when an oblique pile broke.

The up and down stream vertical piles are (in the present design) prevented from swaying transversely to the stream, by the double bracing and cross girders alone. These do undoubtedly give lateral stiffness to the piers, but the detached piles act upon the centre piles supporting the roadway through these bracings and girders, at considerable leverage, and were they to be fractured, it appears to me that the danger to the pier would be much greater than that formerly occasioned by the fracture of an oblique pile, from the very fact that the attachment is so strong.

I admit that the up and down stream vertical piles are, when secured by cross girders and bracings, much less liable to vibration than the old oblique piles, and that vibration was a fruitful cause of fracture, but I be-

lieve if one of the vertical detached piles did break from any cause, the result would be very disastrous

With regard to item No. V., the theory on which the recommendation for these piers rests, is that it is desirable to give rigid points at short intervals to prevent continuous movement acting through the superstructure. I am somewhat doubtful if this synchronous movement ever took place to a serious extent from the simple action of the flood on the piers, but I consider that the buttress piers would be of real service if they were so designed as to prevent the transmission of strains beyond them, and thus limit disaster, like the buttress piles of a masonry bridge, to the intermediate piers

This service, the cluster piers, as they existed at the time of the recent accident, were incapable of performing,—indeed, I consider that they were likely rather to assist in transmitting disaster to contiguous piers than to check it It has been noticed in the case of single piers, that if one end of a girder falls from the failure of a pier or abutment, the other end will generally fall clear of the single row of piles upon which it rested and of the bracing between them, and that were it not that the superstructure is held to the standards by the fishplated rails and timbers, the injury would, as a rule, be restricted to the point of original failure, and would not extend further.

But now if the pier next to a cluster pier gives way, and the girders fall, they will at once become entangled in the outer row of piles and bracings in the cluster.

The enormous strain thus brought on these piles may easily be conceived to be capable of deranging the centre row of the cluster on which the standards are supported, and of thus causing the fall of the end of the next bay of superstructure, (which has only 15 inches of bearing) among the outer row of piles and bracings on that side.

I observe that Mr. Mathew proposes to deck the top of the cluster piers in the Nerbudda, possibly with a view to obviate the risk of such an accident as is above suggested, but I do not think the remedy is sufficient, and, at all events, at the time of the late accident, the cluster piers were liable to this risk.

While, therefore, I have no doubt that the design of the cluster piers might be so modified as to be free from objection on this score, and while I think it is pretty well established, by the Reports as to the con-

dition of the Mhye and Nerbudda bridges during the floods of 1867, and of the Mhye bridge during the flood of last August, that these piers add to the rigidity of the bridges, diminish the general tremor formerly felt in them during floods, which tended to loosen bolts and braces, and add to their steadiness when crossed by trains, I am of opinion that as they existed in the Nerbudda at the time of the recent accident, they produced a new source of danger

With regard to Item No VI, I am of opinion that, although in the piers of five vertical piles covered by cross girders, the roadway would be supported in the event of any one pile breaking, *so long as the other piles remained intact*, the failure of a pile would still be a most dangerous occurrence. A loose pile swinging in the braces, and tearing away at the attachment to the cross girder, if it were not speedily detached or secured would be quite sufficient to destroy the pier after a time.

The advantage of the cross girders is that they admit of piles being removed for repairs, that they prevent the *immediate* fall of the roadway in the event of a pile being fractured, and give some time for the adoption of measures to detach or secure the fractured portion; and that they render the piers more rigid.

With regard to Item No VII, I cannot regard the fenders, as now supplied, as thoroughly sufficient Two up-stream piles, with a 24-inch teak baulk strapped to them, were broken in the Nerbudda in the flood of 1867, and trees brought down by floods may occasionally strike other piles which have no protection whatever. Pile No 3 in Pier 26 was found cracked four joints from the top after the flood of 1867 The pile was only put up the season before, and it is not probable that it was cracked when erected. It may have been struck by a tree, and it is not easy to account for the fracture in any other way, as there were no broken bracings in this pier Unless the destructive effects of heavy timber during the floods of 1864 and 1865 in the Mhye and Nerbudda were greatly overrated, the piers are very inadequately protected now.

With regard to Item No. VIII., I fully recognise the necessity for screwing the piles down below the reach of the scour. The attempt to rescrew the piles will, moreover, demonstrate practically whether the bolts at the joints underground are to be relied upon, as if these bolts have deteriorated, they will give way under the operation.

With regard to Item No. IX., any measures which will render the

joints more secure and less dependent on the bolts for security is a good one, but I would observe that, if this addition is necessary above ground it says little for the security of the joints below ground. In the piles of the Nerbudda Bridge the lowest joints next the screw, and in some cases the next joint also, has inside flanges, the other joints are all formed with outside flanges. The bolts in the inside flanges can be tightened up by divers during the operation of screwing as the pile descends, and before it is filled with concrete, but the outside flanges cannot be touched when they are once below the ground The joints are subjected to great strain during the operation of screwing, and the wrought-iron bolts have to take this strain. Subsequently, they are liable to deterioration, which is more or less rapid according to the composition of the water or subtrata In the Nerbudda, the deterioration is not supposed to be rapid, and the bolts in inside joints are protected by the concrete filling, but the water contains a good deal of salt at certain seasons. It may be urged that the lower joints, which are below the ground, are rigidly fixed, and not liable to vibration like the upper ones, but the lower joints are some times exposed by scour, they are not braced together, and the point at which fracture is most likely to occur, whether a pile is forced over by the force of the stream, or dragged over by adjacent fractured piles or falling superstructure, is a point below the loose surface of the river-bed In the smash of 1864, two-thirds of the piles were thus broken.

Two cases of open joints below ground have recently been reported. In Pier No. 34, Pile No. 4, Mr Curling reports, on the 18th September 1868, "This pile is also open at the joint, on one side $1\frac{1}{2}$ inches, and on the other $\frac{1}{2}$ inch, the flange is also drifted to one side $\frac{1}{2}$ inch." The joint in question was an inside flange joint, and was exposed by scour during the recent floods. Again, Mr. Banks reports of Pier No 38 cluster, speaking of one of the extra piles recently screwed (*see* Plan with Report, dated 23rd October 1868) —"This joint between a G and E pile has shifted laterally $\frac{3}{4}$ inch and opened $\frac{1}{4}$ inch not able to ascertain at present if bolts are broken" The joint between a G and E pile has inside flanges.

Before proceeding to draw a final conclusion as to the causes of the repeated failures of the bridge, I will refer briefly to the most recent accident, that of August 1868. A cluster pier, and a single pile pier on each side of it fell. It is argued that the cluster pier must have been under-

mined by scour The reasons urged in favor of this view are—that it is known that some of the piles of the cluster were not down to clay; that there was a scour of 5 feet at Pier 23, and 6 feet at pier 27; that no remains of the piles have been found in the river-bed, and that a pile screwed in 1861, and subsequently dismounted and abandoned but the lower joints of which were left in, cannot now be found, though it is known to have been seen by divers last season. That while it is easy to account for the failure of Piers 24 and 26 on the supposition that cluster Pier 25 failed first, it is not easy to understand how the destruction of Pier 25 could have resulted from the failure of either of the other piers.

On the other hand, it appears from the sections that the deepest piles in the fallen piers were from 20 to 30 feet below the surface of the river-bed in October 1867, and that in the cluster pier, the shortest piles were 14 feet below the bed, and as far down as the shortest piles in Piers 27 and 28 which stood. It further appears that there is no clear evidence of scour having taken place to a depth of more than 5 or 6 feet, and that the fact that the piles cannot be found on the surface is not very extraordinary, the same thing having happened with two-thirds of the broken piles in 1864, and it being known that the river-bed silted up at this rate almost immediately after the accident to its old level.

I have, in my notice of the cluster piers, suggested what it seems to me is another possible interpretation of the disaster. Pier 26 was an acknowledged point of weakness, and it had a cracked pile in it. It was attached to the cluster pier by the superstructure down-stream, but the up-stream pile was detached under the 90 feet girder, and the pier consisted of three vertical piles only. It was strongly braced to the piers on either side by rod-iron. Suppose pier 26 to have been carried away, the superstructure on the down-stream side would have fallen among the detached piles and bracings of the cluster pier. This and the drag from the ties of rod-iron may have displaced the centre piles of the cluster with the result indicated in page 221, and the destruction of the cluster pier may have followed. The destruction of pier 24 is thereafter easily accounted for, as in these cases the piers will give way one after the other until the *debris* of the superstructure tears itself clear.

I only put this forward as an alternative mode of accounting for the accident. We have as yet no certain evidence to go upon, the best evidence we can yet hope to obtain is from the state in which the fallen piles

and superstructure are found, if they are ever recovered at all. If the piles of the cluster were scoured out, we ought to find the screws attached to them, and perhaps something may be gathered from the position of the superstructure in the river-bed. I trust every endeavour will be made to obtain fresh evidence of this kind.

I would by no means be understood as underrating the danger of having short piles in a river like the Nerbudda, full as it is of shoals with strong tidal currents, and a mouth perpetually changing through the action of the tide in the Gulf of Cambay. Great variations in the position of the deep-water channel must be looked for, and it is impossible to predict the effects of any heavy fresh coming down the river. Under the circumstances, all that an engineer can do is to place his foundations below the depth of the maximum line of variation, and make his work independent of the annual change in the river-bed. It was always intended that this should be done in the Nerbudda Bridge, and it was understood till lately that it had been done, but it now appears that some of the records, both of the depth to which piles have gone down, and the nature of the soil met with, are unreliable.

But apart from the question of defective foundations, I am of opinion that theory and experience prove two things with respect to the Nerbudda Bridge :—

First—That the failure of a single pile, especially at night, may still (in spite of all recent improvements and additions) result in the failure of a pier, and the failure of one pier in the destruction of other piers to an indefinite extent.

Secondly—That the piles upon the stability of which every thing depends, are so weak, both above and below ground, and so liable to accident individually, from blows of timber, from vibration, from loose bolts, from defective or corroded bolts, and from the unsuitability of the material of which they are composed, to resist tensile strains, and its liability to fracture, that they cannot be relied upon in such a dangerous river as the Nerbudda.

The conclusion I have come to is that past failures can all be traced to the inherent weakness of the piles themselves; that although faulty or careless construction may have aggravated the defects of the piles, the best possible work would not remove those defects; that the measures that have been adopted or proposed, to strengthen the piles, may in some

degree lessen, but will certainly not remove, the risk of future accident, and that to secure a permanently safe passage across the river, a different design must be adopted for the piers in the exposed portions of the bridge

It does not necessarily follow that these piles must be condemned universally and in all situations, or that every bridge in the line, or even the whole of the Nerbudda Bridge, need be at once rebuilt In many cases, the present design, with certain modifications in details, may answer well enough. The Nerbudda is an exceptional case, and should I think, be treated exceptionally.

I have endeavoured in this Report, and the accompanying history, to place the whole argument before Government fully and impartially I have not knowingly omitted any points bearing on the subject, but it might be as well, especially if the question is referred to an engineer who is not acquainted with all that has passed, to have all the Reports which I have referred to, including those written by the Government Officers, printed together in full Both Mr Currey and I have already expressed our anxiety for the appointment of an engineer of experience, whose opinion will be respected by all, to investigate the subject, and I am glad to find that Government have concurred in our view, and recommended that this course be adopted.

Before closing this report it will be useful to notice the past and prospective expenditure on the Nerbudda Bridge.

No accurate account of expenditure on the bridge was kept in former days Mr. Sanderson, in his report of the 6th February 1861, stated that the expenditure had then amounted to Rs. 15,11,346, and that he expected the work to cost Rs 1,85,000 more before the bridge was ready for traffic. It is perfectly safe to assume that up to the date of the disasters of 1864, since which time the additional works have been regularly estimated for, the bridge had not cost less than Rs. 20,00,000, while the total expenditure incurred or to be incurred at the Nerbudda amounted to Rs 42,36,268, or, deducting the cost of the second set of six spans on the south bank, the necessity for which is doubtful, will stand at about Rs. 40,00,000

No. CCXXXVIII.

DRAINAGE OF BOMBAY.

Report on a Project for the Drainage of Bombay. By CAPT. HECTOR TULLOCH, R.E.,

UNTIL the publication of Mr Rawlinson's last Report on the Drainage of Bombay, dated January 1868, the prevalent idea in the town seemed to be that the sewage should be discharged into the harbour. The reasons for this proposition have never seemed to me at all satisfactory The greatest argument in its favour is that Bombay lies to the windward of the harbour. Almost every other consideration will convince us that the harbour is badly suited to the purposes of an outfall

I will first show the aspect of the question from a physical point of view. If the Island of Bombay sloped down towards the harbour there would manifestly be a great advantage in taking the sewage in that direction, but the slope of the greater portion of the Island is actually in the contrary direction—right away from the harbour towards the west It is clear, therefore, that if the outfall is situated in the harbour the sewage will have to flow in the opposite direction to that in which it would flow if left to itself. Now the only way in which this could be effected would be by putting the sewers at a great depth below ground, so, on the face of the thing, we should be driven to a most expensive expedient to carry out an arrangement for which, as I shall presently show, there is no necessity.

If, however, the sewage were discharged into the harbour, would the inhabitants be rid of it? In considering this question it should be borne in mind that the only facts we have on record to guide us are Mr. Jag-

gonath Sadasew's float experiments. They are valuable so far as they go, but they are very imperfect Such as they are, however, most people who reason on them will probably come to the same conclusion This is, that casting the sewage into the sea on any point on the eastern side of the island may be attended hereafter with some risk to the health of the inhabitants, and that much nuisance must inevitably arise to the shipping from such a course of proceeding It may be contended by a few that the sewage, being mixed with so large a body of water, would become extremely diluted, and thus be rendered harmless. I am not of that opinion

I am told that the nuisance even from the present main drain of the Fort is at times very great. Even if this were not so, I should still hesitate to draw the inference that because there is no nuisance at present from this drain, therefore there will be none in the future from the main drain of Bombay. The nuisance from foul matter of any kind must, *ceteris paribus*, be directly proportional to its quantity Now the main drain of the Fort is, comparatively speaking quite an insignificant work. It conveys away the sewage of only about 80,000 people, and does this under an incomplete system of drainage. When Bombay is drained under a complete scheme, the main drain, wherever it may be situated, will have to discharge the sewage of nearly one million people, and fifty years hence, of probably two millions of people Let me try and convey to the mind what this means. It means 4,400 cubic feet of sewage every minute, night and day without interruption. Wherever on the coast such a large quantity of filthy matter is discharged, I maintain that it will make its presence known. Indeed, the most serious consequences might arise if we acted on a judgment, founded simply from considering the main drain in the Fort, which, except during rainy weather, has not more than 12 inches of water flowing through it during the day.

What gives Bombay its importance in India is its magnificent harbour. No other town in the peninsula offers such great facilities to the shipping trade as this favoured little Island. If it is the harbour which makes the town, as I should fancy all will admit, would it not be indiscreet, to say the least of it, to do anything that should detract from the advantages which that harbour holds out to all the world to trade with India? Before, therefore, discharging the sewage into the sea at Colaba, should it not be shown by the advocates of that measure that the sewage could not return to the harbour nor cause a nuisance there? Can these proposi-

tions be maintained with even a show of reason in the face of Mr Jaggonath Sadasew's float experiments, all of which with hardly an exception, go far to prove the direct contrary? Could even the majority of those interested in the question be got to believe in them? Until it is clearly demonstrated that the sewage of Bombay cannot be got rid of otherwise, the harbour should never be permitted to be polluted with it.

Looking at the question of drainage from a purely engineering point of view, and setting aside for the present all sanitary considerations whatsoever, I hope to be able to prove the necessity of the abandonment of the harbour as the outfall. A careful examination of the accompanying map of Bombay on which the levels of the different districts and streets are marked, can hardly fail to convince an engineer that the natural drainage line runs along the following streets —Syed Abdool Rahimon street, Bappo Kote street, Falkland Road, and so on to the Flats This is clearly the valley line, and, therefore, from a *primâ facie* point of view, the direction in which the main sewer should run—provided of course that no objection of a serious nature can be urged against it. There is a very serious objection which compels us to abandon this line That objection is that the present main drain which, in parts, is 20 feet wide, runs along this very valley line. The new main sewer could not be built in this direction without destroying this large drain, which will still be required for the purposes of rainfall. In altering the course of the main sewer, I propose to carry it along those streets which run as close to the valley line as possible

The first advantage which will be secured by adopting the valley as the main line of drainage will be that all the street sewers will have better slopes than could be given to them under other circumstances It is impossible for me to prove this by any amount of writing. But if any one should doubt the statement, he can easily test it by running the main sewer along some other line He will find that the nearer the main sewer runs to the valley the better will be the slopes of the street sewers, and that the further the sewer is removed from the valley the worse will be their slopes. The importance of this can hardly be exaggerated, inasmuch as the successful working of every system of drainage depends more on the slopes of the sewers than perhaps on anything else. The less the slopes, the greater must be the deposit in the sewers, the greater the slopes, the less the deposit.

The second great advantage of carrying the sewage towards the flats is connected with the soil. The main sewer will run in the "alluvium and superficial deposits," the strata which are the cheapest for the engineer to work in. There will be a little rock cutting involved in the branch sewer to the Elphinstone Reclamation, but under any system of sewerage, *some* rock cutting would be necessary. The eastern portion of the Island is separated from the rest of the town by a ridge of hills of trap rock It would therefore manifestly be impossible to bring the sewage of the two districts to one point without passing through the hills

If the depth of cutting which always materially affects the cost of drainage works be considered, it will be found that it is far less, under the proposed system, than that which any other line of main sewerage would involve. In fact, the depth of the cuttings will be moderate throughout, and wherever rock abounds, there the cuttings for the street drainage will be reduced to a minimum.

But perhaps the greatest of all advantages will be of a prospective nature. In an important town like Bombay which has already set up its claim to be considered the capital of India, and which is increasing in size, population, and importance every year, no system of drainage should be adopted which will not suit her growing requirements The scheme to be carried out should be so comprehensive that in whatever direction the town might spread, the drainage of the new parts should fit in at once with that of the old. I do not mean that the system of drainage should be so complete that nothing further should be required, for that would be absurd. New works must be executed as the town spreads, but they should still form part of one grand scheme They should be additions to that scheme, not systems apart from it.

I am given to understand that the direction in which the town has always shown a tendency to spread is towards the Flats. Now as this is the direction in which it is proposed to take the sewage, it should be clear to every one that this is the very part of Bombay that would drain the best of all. The main sewer would pass through the Flats and of course the most rapid falls could be secured for the street drains.

But this is taking a very simple case. I will put a much more difficult one. Suppose the town were to spread a mile beyond Parell, or suppose even that the whole island were to be covered with habitations, how would the proposed project answer in that case? My reply is that this project

has been expressly designed for the drainage of the whole Island. A short inspection of the accompanying map of Bombay will show that the lowest portion of the island is the valley running from the Flats right up to the northern coast. Now if the entire island were thickly populated, all that would be required for its drainage would be to carry a sewer from the north along the bottom of this valley to the Flats. I have so arranged the levels of the proposed works that this sewer would be at a sufficient depth below ground to drain the whole of the island effectually, and would enter the Pumping Station at Love Grove at the same level as the sewer from the south. In other words, all the sewage of the future town of Bombay could still be concentrated at one point, to be there dealt with under one management. And this brings me to the question of pumping.

Whatever outfall may be selected it is a physical impossibility to discharge the sewage without the help of pumps. A large portion of Bombay lies below high tide level. Some parts of the island are elevated only a few feet above low water mark. Under these circumstances it is clear the sewage could not be made to flow into the sea without artificial aid. Nor is the case altered if we decide to utilise the sewage on land. There is no land lying at a sufficiently low level and away from the influence of the tides, on which the sewage could be used without first being raised. It is thus a matter of necessity (in which the engineer has no choice at all) to employ pumping in order to get rid of the sewage. If this truth be recognised as established, I will try and point out the advantages to be gained by leading the sewage towards the Flats.

The Flats near Love Grove are, I should fancy, too well known to need any description at my hands. It is universally admitted among sanitarians that a high death rate generally accompanies swampy ground. Indeed, one of the most essential conditions of health is a dry dwelling. Dirt and stagnant water abound in low lying districts. If we rightly estimate the value of houses free from damp we must see the importance of preventing the Flats from being inundated, as they now are, *i. e.* for about five or six months together at a time. I feel certain that the reclamation of the Flats would in a very short time be followed by a reduction in the death rates throughout the town, and no drainage project therefore should command the confidence of the inhabitants which ignores the necessity of preventing the formation of swamps in the island.

It has been proposed to raise the Flats, but I cannot see what good result, commensurate with the cost, would follow, unless the whole of the island were raised above high tide level It appears to me that the reason why the Flats are swamped has not been sufficiently considered, or the proposition of elevating them would never have been made

Taking mean sea level at 50 feet above datum line, the following will be the levels of the different tides —

High water spring tides, ...	57·25*
High water neap tides, ...	55 00
Mean sea level, ...	50 00
Low water neap tides, ...	45 00
Low water spring tides, ...	42 75

The Flats vary in level Parts are as low as 47 00. There is a considerable area at 48 The average level may be taken at about 49 00 or 50·00 and the highest level at 54

Now when a storm overtakes the town it depends entirely on the state of the tide at the time how deep the lower parts of the island are under water. The greatest storm that has ever visited Bombay during the last 20 years was that of the 9th of August last, when 14 21 inches of rain fell in 24 hours. Parts of the town were three feet under water. The level of the water on the Flats was at 54 50 above datum, and the level of the water in the town stood as high as 58 00. The tide rose to 55·83. In such storms, the rain collects on the Flats very much quicker than the sluices at Love Grove and elsewhere can discharge it, and the effect of raising the Flats without enlarging the sluices would simply be to throw a larger body of water on to the town. The water must accumulate somewhere. It cannot escape to the sea, because the sluices are not nearly large enough. During spring-tides the sea would for several hours be higher than the floods, and the sluices could not be kept open at all. Where then is the water to stay during this time if the Flats are raised?, It is evident that it must run to the lower parts of the island wherever they may be, and these will then take the place of the present Flats and become the swamps of Bombay in their turn. So that all we shall have done by elevating the Flats will be virtually to remove them to some other locality. Would this be worth the expense?

* To reduce these levels to Colonel DeLisle's datum add 20·70 to each.

The fact is that, before the Breach Vellard was constructed, the town was not liable to floods by rain, because the rain could always escape to the sea It was, however, liable to floods by the sea, because the sea could enter through the breach. The construction of the Breach Vellard has solved only half the problem It has kept the sea out, but unfortunately it has also kept the rain in. No one can doubt this who has been in Bombay during the months from June to November. The Flats are always under water at that time. The remaining half of the problem is, cannot the rain be allowed to flow into the sea so that there shall be no swampy ground at all in the Island? I am certain it can Even after such an extraordinary storm as that of the 9th of August last, if proper arrangements had been previously made, the Flats should have been dry the day after.

If I have rendered myself clear, it will be seen that, during heavy falls of rain, some part or other of the island must be under water; that if, in order to prevent this state of things it were determined to raise the lower lands, no part of the island should be allowed to remain below the level of high water of extraordinary spring tides, or below $60\frac{1}{2}$ above datum Unless this were done, there would still be portions of Bombay liable to be flooded. But to raise the lower lands to anything like this level would be pecuniarily impossible, it is altogether out of the question, I do think, therefore, that the idea of relieving the town of floods by raising any part of the Island should be entirely abandoned The difficulty must be overcome by other means, but, before pointing them out, it is necessary that the object in view should be kept in mind.

The area which drains into the Flats and the lower parts of the island is 16 square miles. The greatest fall of rain during the last 20 years is 14 inches in 24 hours, and this amounts over that area to 520,000,000 cubic feet. This is a tremendous body of water to deal with, but we know for a fact that this quantity did actually flood the island on the 9th of August last, and it would not be right to ignore the circumstance. The problem which I have set to myself, therefore, is this. Can 520,000,000 cubic feet of water be run off into the sea in one day during those hours when the tide is below the floods? The question is immensely complicated by the fact that the problem varies with the state of the tide when the storm takes place. If spring-tides are prevailing, the sea must rise above the level of the floods, which cannot, in that case, be discharged for

many hours of the day. On the other hand, if neap-tides are prevailing, there will be very few hours when the floods may not be relieved. At a first glance, therefore, it would appear that the most unfortunate state of things for the town would be for a great storm to take place while spring-tides prevailed. But this is really not the case The worst state of things is when a storm occurs during neap-tides, the very worst of all during extraordinary neaps. A little consideration will render the matter clear.

During spring-tides, the sea rises of course very much higher than during neaps, but on the other hand, it falls very much lower, and this is of the greatest importance. The head of water in the former case is considerably more than that in the latter, and the consequence is that during the hours at spring-tides when the sea is lower than the floods, much more water can be passed off than during a greater number of hours at neaps.

It is evident, therefore, that if during neap-tides the floods can be relieved in 24 hours, of a storm of water over the island amounting to 14 inches in that time, we shall have provided for the worst state of things—a state that may not occur in 50 years. I propose, therefore, to construct three sluices each 120 feet long—one at Love Grove, one at Worlee, and one at Daravee. These works with the present sluices, will in one day discharge all the rain (taken at 14 inches in 24 hours) which falls on the area draining towards the Bombay swamps That is to say, that if a storm similar to that of the 9th of August last occurs even during neap tides, the whole of the water standing on the island will be discharged into the sea within a single day.

The difficulty has not yet been entirely got over, for there is another point demanding consideration. This is, that in great storms, during those hours of the day when the sluices cannot be kept open, the lower parts of the town may still be liable to floods in consequence of the rain not being able to run off to the Flats as rapidly as it falls. In fact, the question is whether the state of things which occurred on the 9th of August last can be prevented. It may be quite true that all the floods might, with proper sluices, have been discharged into the sea in 24 hours but would not the water still have collected in the town itself, as it actually did, while the sluices could not be kept open, and in consequence of the mouth of the main drain being dammed up by the floods on the Flats?

This is a very important question, and will show that another great advantage has been secured by this project.

I have already pointed out that pumping must under any circumstances be resorted to before the sewage of Bombay can be disposed of. By leading the sewage towards the Flats we shall require the engines to be erected there. Now these engines, in a time of great emergency like a storm, will be most admirably situated for two purposes, in addition to their ordinary one, viz. that of pumping up the sewage only. The first is that of helping towards relieving the Flats, and the second, which is much the more important one, is that of keeping the town from being flooded. We can afford to let the Flats lie under water for a few hours, as nobody will be inconvenienced thereby, but it would never do to let the town get swamped.

There will be three engines, each of 150 horse power. Two of these will be sufficient, in ordinary dry weather, for pumping the sewage to the irrigation lands. In times of extraordinary storms (but not oftener on the average than once a year) the sewage for a few hours might, with hardly any nuisance, be pumped into the sea. If this were done, one engine would be enough for the purpose, as the lift in that case would be only half of that required when the sewage had to be raised for irrigation. Two of the engines would thus be free for keeping the town dry, and if the work of the third got slack, that is to say, if it were the time of day when there was little or no sewage, even the third engine could be put to the other duty. And if all the engines were worked to their utmost power, there would be about five or six hundred horse-power employed in pumping the town dry.

These engines would draw the water directly from the town itself by a sewer running under the Flats, and so arranged that the floods on the latter would be entirely excluded from the sewer. In fact, the rain would be allowed to collect on the Flats, but not in the town. The Flats would be relieved as soon as the tide went down, and so too would the town itself, but while the sluices could not be opened and the rain continued, the engines would be exerting their utmost power to keep the town dry, and, even in the rare case of a great storm occurring simultaneously with a neap tide, they would still, I believe be successful in effecting the desired object.

If extraordinary neap tides prevailed during the storm, it would be

impossible without the help of pumps to get the Flats dry, because at no time of the day would the floods be entirely above the level of the sea. Low water of extraordinary neaps is 48 75 feet above datum, and parts of the Flats are as low as 47. Over these parts, therefore, there would be nearly two feet of water standing which could not escape through the sluices even when the tide was at its lowest In this very peculiar case, after the town had been relieved, the engines would be set to work to pump the floods on the Flats, and the whole island would be dry in the course of a few hours.

Now it should be clear that such a number of advantages could never be secured by a project which had its engines erected on the harbour side of the island to pump the sewage into the sea in that locality. By placing the engines on the western edge of the Flats we shall be near the sea, and we shall have them in the very best position to meet all emergencies arising in times of great storms.

If, as I have shown above, some part of the island must be under water for some hours during heavy rain, I trust it will be granted that no object will be answered by raising the flats. Indeed a very important one will be gained by letting them be what they now are. at present, they form a reservoir for storm water while the sea rises above the floods, and for this object I would still retain them.

Numerous projects appear to have been put forward for reclaiming the Flats, with the view to fit them for building purposes. But why should the Flats always be selected as eligible ground for this object? They are covered with foul matter, and I doubt whether the best sanitary arrangements would make them habitable. It is much more probable that if this portion of the island were built upon, it would become the centre of disease in Bombay, from which every one would more or less suffer

I should be the last to advocate that the Flats should be converted to no useful purpose at all, or that we should rest satisfied with having relieved them of floods. On the contrary, I would have them not only negatively harmless, but I would make them positively healthful—a place where all classes might go for recreation, amusement, and even for pure air!

Bombay, with its million inhabitants, has no park; why should not the Flats be made into one?* The more the subject is considered, the better

* For the position and extent of the proposed park, vide Plan The idea of a park was first suggested to me by Mr A T Crawford, the Municipal Commissioner of Bombay, to whom, therefore all the credit for so excellent a proposition should be given.

it will look That very filth with which this part of the island has been for years covered, has rendered the soil rich enough to produce any thing. In place of a fetid swamp reeking with emanations from all kinds of the foulest matter, we should have a garden in which it would be a pleasure to walk. Somebody has well said that "dirt is matter out of place," that is just the case with the dirt on the Flats, but it will certainly not be so if this proposition of a park is carried out Manure is offensive only while there are no crops growing on the soil, but as soon as the field is green the nuisance vanishes It is wonderful with what rapidity the foulest matters are absorbed and assimilated into their systems by plants. It is precisely because the Flats are so filthy that they are so well suited for a park.

If we consider the position of the park with reference to future Bombay it is very favourable The town must spread towards the north, for the southern portion of the island is nearly as thickly populated as it well can be, the park would thus stand about midway between the old and the new town, and be equally convenient for the inhabitants of either.

From a financial point of view the question looks equally well. The land already belongs to Government, it will therefore cost nothing to purchase. It would be a noble act on behalf of the Government to present it to the Municipality for such an excellent purpose. I feel confident that hereafter, when the Flats are reclaimed and the soil is cultivated, the park will not only pay its own expenses but be a source of profit to the town.

I have all the greater confidence in urging this proposition on the people of Bombay, because I have seen a park spring up under similar circumstances in another large Indian town, and prove to be a great success Only a few years ago, the People's Park in Madras was a swamp and a receptacle for the filth of the town—a place which every one avoided if he could, which literally stank in the nostrils of the inhabitants. Now, it is one of the loveliest gardens, to which all classes resort during their hours of leisure Hardly any one could have anticipated the immense success of the undertaking There is no reason which I can see that should prevent the Bombay Park being equally successful It will never do to let the town spread indiscriminately in all directions without preserving some open spaces for health and recreation. The time must come when the people will demand a place of this kind. Now there is the chance of

securing land at nobody's expense, and, if the opportunity is allowed to slip, the people will have themselves only to blame for it

I need hardly point out that all the property about Mahaluxmee, Tardeo, Cammateepoora, Byculla, Chinchpoogly, Worlee and other adjacent districts will be immediately enhanced in value if the Flats are reclaimed as proposed in this project, and still more if they are converted into a park

Having already shown the numerous advantages that will be secured by taking the sewage in the direction of the Flats, it is necessary that I should explain what is intended to be done with it My opinion is that Mr Rawlinson's proposition to utilise the sewage overcomes all difficulties regarding its disposal But before entering on this question, I wish to answer the arguments of those who, being opposed to this scheme of sewage irrigation, might be expected to put forth their objections somewhat in this form. Of course if sewage can be utilised, there is no doubt that is what should be done with it, but it is questionable whether it will succeed in Bombay, and if it does not, will not this project be a failure, and will not all the expense that the inhabitants will have been put to in leading the sewage towards the Flats be thrown away? Giving the objectors all the advantage they may claim on this ground, I will assume that sewage utilisation turns out not only to be a failure, but to be the most miserable of failures—that not one blade of grass nor a pound of vegetables can be grown—that the land refuses to yield any produce of any kind, apply the sewage how we may, then I maintain that, even in this case, it will be far cheaper to take the sewage to the Flats and to pump it up there, than to carry it direct to any other part of the island. It hardly matters at all to this project, and that is a great advantage, where it may be decided to take the sewage to ultimately.

For the sake of argument, I will assume that its utilisation having proved a failure, the sewage is to be discharged into the sea on the harbour side of Colaba. The only difference then, in this project, would be that the irrigation pipe which would have been taken to the north for the tilisation of the sewage, would have to be carried to the south to disrge the sewage into the sea. No land would, therefore, be required gational purposes. The result would be that *an actual saving of estimated price of that land) would be effected* I hope this satisfactory answer to those who think that, by permitting the

town to be drained to the Flats, the Municipality will be pledged either to sewage utilisation or to adopt any particular outfall for the sewage. On the contrary, the Municipality will be free to cast the sewage at whatever outfall they may hereafter discover to be the best, and *at a cost less than that of this project* The only work that need be suspended in carrying out this scheme is that of the irrigation pipe, which, if sewage is found valuable, can be laid down to the agricultural lands in the north, and which if sewage proves to be worthless, can be carried to the south

I must repeat here that I have spoken of the failure of sewage application, not because there is the least doubt in my mind of its success, for I have never had any such doubt at all, but because I wished to argue the question of the advisability of draining the town towards the Flats from the point of view of those people who, being opposed to sewage utilisation, take their stand upon the ground that the Municipality will commit a grievous error to adopt Mr Rawlinson's Project The fact being just the reverse, viz. that the Municipality will be as independent in their action, with regard to the ultimate disposal of the sewage, as they could possibly be

It is not my intention to argue the question of sewage utilisation. It would be impossible by any process of abstract reasoning to prove its success to the satisfaction of those who are opposed to it It is a matter of practice, not of theory. If I wished to maintain my point, I could not do better than describe all the sewage farms which I have seen in Europe But even if I did this, the opponents to sewage irrigation would probably reply that India was not Europe, and if I answered that India was better than Europe—that the conditions of success in India are more favourable than in Europe—that a greater number of crops can be got off land in India during the year than can ever be produced in Europe—that while land in England has to be drained, the soil in India thirsts for water—to all this my opponents could urge that, in the absence of actual experiments with sewage in India, my statements were mere assumptions, and therefore valueless. The end of such an argument would simply be a dead-lock.

Under these circumstances, it would answer no useful purpose to enter on this discussion. I am quite willing that the matter should be decided by direct experiment There will be plenty of time before the irrigational part of this project is carried out, for the conversion of the most sceptical

There is only one argument which I think it necessary to meet. It

may sound very absurd, but it is really the case that, in some towns in England, Rugby for instance, such a large quantity of food for cattle has been produced by the help of sewage, that there has been the greatest difficulty in disposing of it. Croydon, being near London, and having thus a ready market for her produce, has always been able to sell it, but the town of Rugby could not for a fact, get her produce consumed. The town had to purchase cows and to establish a kind of farm, in order to dispose of the crops. Now in Bombay this is not likely to occur. The prices of vegetables, and all kinds of garden produce for human consumption, are extraordinarily high, and especially is this the case in the dry months when water is scarce. A different state of things will exist when the sewage is utilised. There need be no fear of overstocking the markets, for Bombay has a population of nearly a million people, and many of her wants are badly supplied. Milk and butter, the two articles that can be produced most successfully and in the largest quantity by the help of sewage, are at extraordinary prices. Bad butter is twice as dear as the best in England, and buffalo's milk fetches three times the price of cow's milk at home. Italian rye grass, of which I anticipate that from six to eight crops will be taken yearly off the land in Bombay, will find a ready sale. The Municipality would require large quantities for their bullocks of which they keep from three to four hundred pairs. Thus, a direct return would be obtained by the town for their expenditure on the drainage, and this would certainly not be the case if the sewage were cast into the sea.

Before closing this subject, I beg to add that, as the sewage is proposed to be utilised several miles from Bombay, no possible objection can reasonably be made to this part of the project, on the score that the inhabitants will be subjected to a nuisance. Sewage lands, if the irrigation is carried on properly, give off no noxious gases. It is difficult to believe this, unless one has actually stood in a sewage field. But those who may differ from me in this respect could hardly maintain that any mischief will arise to the town if the sewage is applied to the land so far from Bombay as is proposed.

[*To be Continued*]

No. CCXXXIX

SUN-DIALS.

By LIEUT. H WILBERFORCE CLARKE, R E.

IN times gone by, Sun-Dials, as measurers of time, were matters of great interest and utility.

The introduction of cheap, yet well made, watches, and of other measurers of time has caused them to fall into disuse in civilised countries; but here, in India, where from various causes watches are very liable to get out of order, and where there is always a difficulty in getting them repaired, they might be used much more than they are, and with great advantage

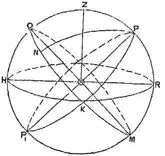
In the hope of setting the subject, simple in itself, in a simple state before those who may be desirous of information on the subject, I venture to discuss, in this paper, the different methods of construction.

Part I.—In order to make the matter intelligible to all, it will be well first to define those lines which it is necessary to consider in the construction of Sun-Dials.

Let *Fig* 1. represent a Celestial Sphere; that is, the sphere of illimitable radius described about the observer O on the surface of the earth.

Then Z is the observer's zenith, being the point immediately above him

Fig 1



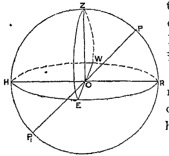
HKR, a plane perpendicular to ZO, is his horizon

Let PP′ represent the axis of the celestial sphere, *i. e*, axis of earth prolonged, then the plane QKM is the equator, being perpendicular to PP′.

The great* circle ZPMH passing through the zenith Z, and the pole P is the meridian of the observer

Let, in *Fig* 2, the great circle EZW (only half is drawn to prevent confusion of lines in the figure) passing

Fig. 2



through the vertical ZO, be perpendicular to the meridian HZPR, then EZW is called the prime-vertical and the points E W, are the east and west points, supposing P to be the north-pole.

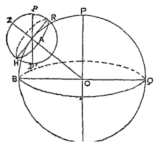
A great circle, passing through the zenith is a vertical circle, thus EZW is a vertical circle, but, in its particular position, it has the name of prime-vertical

The great circle passing through the pole, perpendicular to the equator, is a circle of declination thus NP in *Fig* 1 is a portion of a circle of declination.

The elevation of the pole P, above the horizon RH † is the latitude of the observer.

* A great circle on a sphere is that which is cut by a plane passing through the centre of the sphere.

Fig 3



† Let BPQP, be the earth PP, the axis, BQ, the equator, A, the place of the observer,

About A describe the celestial sphere, then Z is the zenith of the observer, HR his horizon, *pp*, parallel to PP, the axis, and the latitude of A is the angle BOA

Now ∠ ZAR = ∠ BOP, both being right angles

And ∠ ZA*p* = ∠ ZOP, because A*p* is parallel to PO

∴ *p*AR = ∠ AOB = latitude of A.

The angle formed by the meridian and the declination circle passing through the celestial body is called the hour-angle of that body; thus, in *Fig* 1, QPN is the hour-angle of any body, which may be in the arc NP of the declination circle, PZQHR being the meridian.

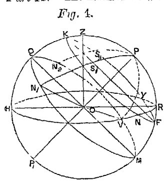
The figures under consideration have been supposed to be made of glass to enable lines, on the reverse side, to be seen; P is considered the north pole, and, consequently, the side of the sphere presented to view, is the eastern; E marks the east and W the West; all lines on the reverse side of the figures are dotted.

These observations are made to facilitate a comprehension of the figures.

On a Sun-Dial, the time is marked by the shadow thrown by a line, representing the axis of the earth upon a given plane,—be it horizontal, vertical, or inclined.

Part II.—The manner in which the shadow is thrown is as follows:—

Fig. 4.



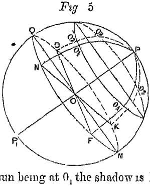
The path a star apparently pursues, is a circle parallel to the equator.

Thus let P be the pole, Z the zenith, HR the horizon, QM the equator then FK is the path of a star

It rises at N, comes on the meridian at K, descends and sets at Y on reverse side of figure, its declination is measured by $N_1 S_1$ and its hour-angle by QPN_1

Now, the star S_1 will cast the shadow PV, and as it ascends, the position of PV will change, the position of the shadow being determined by the declination circle passing, at the time, through the star. The shadow may fall on any plane we please, such as we shall presently consider.

Fig 5



Instead of a star, which is hardly brilliant enough to cast a shadow, imagine a sun, and what really occurs is pictured to one.

In Fig. 5, in which all lines not absolutely necessary are discarded, are shown positions of the sun and shadow. Thus, the sun being at O_1 the shadow is PK, belonging to the declination circle NPK.

The sun being at O_2, the shadow is PF belonging to the declination circle DPF.

Hence, the Problem is, knowing

(1) The position of the axis of the earth, *i. e.* the latitude of the place.

(2) The position of the plane, on which the shadow is required to fall.

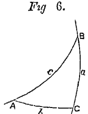
(3) The hour-angle QPN.

To find the space which should correspondingly be marked, on the given plane, to indicate the given moment

Since the sun, apparently, moves through 360° in 24 hours, it must move through $\frac{360}{24} = 15°$ in one hour; or one hour of time = fifteen degrees of space. This knowledge we shall presently require.

We now know what we have to undertake, but to enable us to perform certain steps, we must remember two problems in spherical Trigonometry.

Fig 6.

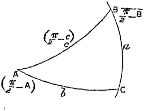


Let ABC be a spherical triangle, right angled at C, it is required to find the relations between the sides and the angles.

For B write $\left(\frac{\pi}{2} - B\right)$, for c, $\left(\frac{\pi}{2} - c\right)$; for A, $\left(\frac{\pi}{2} A - A\right)$ leaving b and a intact, and C out of consideration altogether. Then, by Napier's Rules.

(1) Sin of middle = product of cosines of opposites.

Fig 7.



(2) Sin of middle = product of tangents of adjacents.

We have a, b, $\overline{\frac{\pi}{2} - A}$, $\overline{\frac{\pi}{2} - c}$, $\overrightarrow{\frac{\pi}{2} - B}$

Call any one of these five parts, the middle part; then the two next are adjacent, and the two remaining opposite.

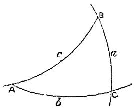
Suppose b to be a middle part.

Then $\sin b = \cos \overline{90 - c} \cos \overline{90 - B} = \sin c \sin B$.

And $\sin b = \tan \overline{90 - A} \tan a = \cot A \tan a$.

Next consider the oblique spherical triangle ABC, then will

Fig. 8



$$\cot a \sin b = \cot A \sin C + \cos b . \cos C.$$

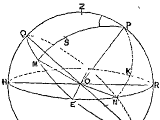
We have, in this equation, four consecutive quantities a, C b, A, in order

Call a, A the extremes, C b, the means.

Then cot extreme side × sin other side = cot extreme angle × sin other angle + product of cosines of those angles whose sines have been taken

The formula in words, rather than that in letters, had better be committed to memory.

Fig. 9.



THE HORIZONTAL SUN DIAL.

Let P be the pole.
,, QMX the equator
,, HER ,, horizon
,, Z ,, zenith.
,, S ,, position of sun
,, PR be the latitude ϕ
,, QPS ,, hour-angle h.

Observe that OP is the position of the style, being the axis of the sphere; that HER the horizon is the plane on which the shadow is to fall; and that PN a portion of the same declination circle as PSM marks the extremity of the shadow. In the triangle PKR, right angled at R, we have.—

$$PR = \text{latitude} = \phi$$

$$\angle\ RPK = QPS = \text{hour angle} = h.$$

$$\angle\ KRP = \frac{\pi}{2}.$$

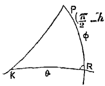
Let KR $= \theta =$ measurement of KOR

Then $\sin PR = \tan (90 - KPR) . \tan\theta = \tan \overline{\frac{\pi}{2}\ h} \tan\theta.$

$\therefore \sin\phi = \cot h . \tan\theta$ or $\tan\theta = \sin\phi . \tan h$,......................(a)

Let h = 2 hours before 12 noon, or 2 hours before passing the meridian.

Fig 10 $= 2 \times 15^\circ = 30^\circ$



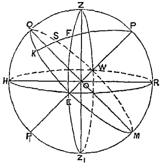
$\therefore \tan \theta = \sin \phi \;\; \tan 30^\circ$

By substitution, all the lines are thus obtained.

The Sun-Dial in the Prime-Vertical.

Let P be the pole, EQ a portion of the Equator; Z the zenith; HER the horizon, ZEZ_1W the prime vertical perpendicular to the meridian $PZHZ_1R$, S the position of the Sun.

Fig 11



The triangle, which we should properly consider, is the one corresponding to ZPF, (in the northern hemisphere), situated in the southern hemisphere, but it is manifest that the two triangles are equal, and therefore, to avoid confusion arising from many lines, we will consider the triangle ZFP.

In the triangle ZFP, we have :—

$\angle$ ZPS = hour angle = h.

$\angle \text{ FZP} = \frac{\pi}{2}$

$$\text{Z P} = \left(\frac{\pi}{2} - \phi\right) \text{ and FZ} = \theta,$$

Therefore, by Napier's Rules,

$$\text{Sin ZP} = \tan \text{FZ}. \tan\left(\frac{\pi}{2} - \text{ZPS}\right) = \tan \theta. \cot h.$$

$\therefore \cos \phi = \tan \theta \;\; \cot h$, hence $\tan \theta = \cos \phi. \tan h$,..... ....(b).

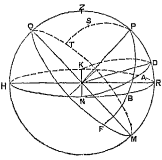
For h, we may put (N 15°) where (N) stands for the number of hours before, or after noon, for which the space θ is required

The inclined Dial

Let P be the pole, QM the Equator, Z, the zenith, HR the Horizon, KND the plane of the dial, inclined at an angle α to the Horizon, S the sun, PST the circle of declination passing through it; PABF a por-

tion of the *same* circle of declination limiting the extent and position of shadow, ZPMH the meridian. In the triangle PAD, we have —

Fig 12



$\angle$ PDA $= \frac{\pi}{2}$,

PD $= \overline{\text{PR} - \text{DR}} = \overline{\phi - a}$,

$\angle$ APD $=$ hour-angle $= h$. AD $= \theta$,

Therefore by Napier's rules.

Sin PD $=$ tan $\overline{90 - \text{APD}}$. tan AD.

Sin $\overline{\phi - a} =$ cot h. tan θ

$\therefore$ tan $\theta =$ sin $\overline{\phi - a}$. tan h, ... (c).

No CCXL.

HOFFMANN'S BRICK KILNS.

Instructions for erecting, lighting and working HOFFMANN'S PATENT KILNS *at the Government Brick-factory at Acra, near Calcutta. By* HERMANN WEDEKINS.

THE grand object of this invention—economy of fuel—is materially assisted by particular attention being paid to a few leading points, and first, by selecting a dry, well-drained site, as any damp rising from the earth is to be carefully avoided; for, should this be present, it not only takes fuel to generate this moisture into vapour for discharging it by the flues, but it has the further serious effect of retarding the burning of the kiln and damaging the burnt bricks, which would show cracks caused by the vapour rising from the ground.

Drainage—After the soil has been taken out, it is of the utmost importance to well-drain the whole site to a deeper level than the lowest flue. From the smoke-chamber round the chimney, a drain is to be laid at a lower level than any of the foundations, and all drains from flues, &c. should have an inclination towards the central chamber, and delivering into this drain. The chimney foundation, likewise, is to be supplied with a drain to carry off the condensed steam running down the inside wall of the stack

Foundation of burning chamber.—The foundation of the two walls forming the annular burning chamber is to be carried down 2 feet 6 inches below the floor-level as shown in Plan for if the material beneath the

floor is composed of clay, or any substance that will contract on exposure to heat from firing the goods over it, it is obvious the foundation would give way, open, and admit air, which is a serious drawback to the working of the kiln. The floor of the burning chamber is to be formed of hollow chambers as shown in sections (*g h*) and (*i k*) of the *plate*, being closely covered over with bricks, on the top of which a stratum of clay is packed about 9 inches thick, and on this rests the paving of common bricks. The lining inside the kiln, including the drop arches at the end of each chamber, is to be made of fire-bricks, or bricks which will not contract under repeated burnings, being able to resist a greater heat than the clay to be burned.

Battered walls.—The outer battered walls of the kiln taking up the pressure from the arch, are to be built as shown of common bricks laid in mortar, *not* bonded with the wall of burning chamber, allowing the latter free motion as required through the heat passing through the kiln In the packed space between the outer-walls and walls of burning chamber, cross-walls or tie of $4\frac{1}{2}''$ work, (it is shown in the plan *one brick*, but *half brick* is quite enough) are constructed, and bonded with the battered walls, but free of all connection with the inner wall, the object being to resist better the thrust during expansion, instead of solely depending on the packing material.

Chimney.—The chimney, which is of a very light construction, consists in its horizontal section, of two rings of 9 and $4\frac{1}{2}$ inches brick-work, respectively. The 9-inch wall is carried up to about 30 feet in height, and then both rings are only built with half a brick each. These rings are bonded and strengthened by radial ties reaching from the base right to the top of the chimney. There are altogether 12 such ties. The short inner tube is constructed inside the chimney to protect the brick-work of the latter, in case an intense heat should, through some cause or other, pass into the chimney, as may happen at the end of the season in burning the last chamber by allowing the gases of intense heat or the flame to pass *direct* into the chimney. This chimney construction is both cheap and strong, and forming an air chamber round the inner wall, the latter is well protected against cooling, which is very important, as the waste steam and smoke possess a very low temperature. At the base, the chimney is provided with four apertures forming the communication with the smoke chamber.

Bricklaying.—The whole structure of the kiln can be executed with bricks laid in mortar in the usual manner, with this one exception, that the two side walls, arch and floor, forming the annular chamber, are to be built with bricks laid in clay mixed with sand to the texture of a good loam. For making firm work, this clay should be made up into a slop of the consistence of thick cream, and *not* used as mortar is generally employed, making a thick joint between each brick and the next following one. The slop or clay being placed conveniently for the workman in a water-tight box, he takes a brick, and dipping those surfaces he wishes to unite in the slop, and well coating them with it, he lays the brick in its place, at the same time forcing it into as close a contact as possible with those next to it He then proceeds with another, and so on It is therefore, obvious that those bricks will rest closely one upon the other with only a thin bed of clay cementing them together, and when the kiln has been burnt round once, it will be found the strongest mode of structure for withstanding the expansion and contraction to which such walls are exposed The outside walls are built in mortar, as well as the *flues*, *chimney*, and smoke chamber, although in many cases even the smoke chamber is constructed with bricks laid in clay.

Arches.—In turning the arches of the chamber, a center must be made to fit one chamber, and this can be lowered and removed to the next chamber in one piece At each end of the chamber, a dropping arch is built $18\frac{1}{2}$ inches " strong to obstruct the draught along the top of the kiln, while they likewise serve as a support against which are placed the intercepting wrought-iron dampers for dividing and separating the chambers, as will be explained below

Radiation.—The main arch of the annular firing-chamber is covered with a stratum of clay from 4 inches to 6 inches thick, and above this, as well as between battered wall and wall of burning-chamber, as well as the whole space between burning-chamber and smoke-chamber, is to be filled with soil or sand, to prevent any heat from escaping, and to prevent the possibility of any damp or moisture finding its way within reach of the heat of the burning-chamber For this reason, it is most desirable to construct a roof over the kiln, under which large quantities of goods can be dried while at the same time, it affords a shelter to the men attending to the firing of the kiln, who, exposed to the changes of the weather, more particularly during the night, cannot be expected to attend to their

duties with punctuality If, however, no roof is provided, the whole top surface should be closely paved on a thick bed of mortar or cement, and when finished, well grouted with cement, to prevent the possibility of water passing through it, at the same time giving the surface a good fall to carry off all water falling upon it.

Iron-work.—The iron-work for each kiln of 14 chambers consists of 14 valves for regulating the draught, and they are built in as shown in Plate on the outlet of each flue in the smoke chamber. The adjusting lids, when seated, should rest on a bed of sand to secure an air-tight joint. From the centre of these lids, a long adjusting rod passes up through the arch of the smoke-chamber, and by means of a cast-iron plate and set-screw, it can he regulated to any height required On the underside of these lids, are fixed three or four iron-bars forming a guide to the valve, which, on being lowered, adjusts it properly in its place Each firing-hole has an iron-pipe built in as shown in Plate with a cast-iron cap fitting in a bed of sand air-tight. Of these 280, or 20 for each chamber, are required. Besides these castings, each kiln requires two large intercepting sheet-iron dampers as shown The damper is brought in through a door-way and placed in its several partitions one above the other against the projecting arch, while in removing the same, the top parts are lifted and the lower parts drawn through the door-way, and after that, the top parts are lowered and removed in the same manner. It is only for convenience sake to have *two* dampers for each kiln, that the work of the same may not be interrupted while the damper is removed. While one damper is placed several compartments in front of the fire, a second damper is placed in *front of the chamber to be filled*, thus the first damper may be removed without interrupting the draught, as the second damper is ready to cut off the draught in similar manner, allowing the waste gases to pursue their course also through this compartment recently filled with green bricks. The best method of placing the damper in its place shall be more minutely explained in a future paper, when the instructions for working and lighting the kilns will follow these instructions for building the kiln.

H. W.

LONDON,
March 8th 1869.

No CCXLI.

THE LUCKAWULLY AND MASOOR RESERVOIRS

Report by CAPT. MULLINS, R.E., *Consulting Engineer for Irrigation and Canal Company.*

Luckawully reservoir.—For this reservoir, the Executive Engineer, Mr Gordon, has prepared a design for a dam at the point where the river Budra passes through a narrow opening in the hills, near the village of Luckawully, and the surplus water is intended to be passed at a detached saddle, about half a mile to the north.

The general features of the arrangement are shown on the accompanying plan, and it will be seen that the dam consists of a wall of masonry and concrete 174 feet high, with a base of 124 feet, and a top width of 5 feet, the batter in front being $14\frac{1}{2}$ feet, and that in rear $104\frac{1}{2}$ feet. The depth of water, when up to the crest of the waste weir, will be 160 feet, and this depth would be liable to increase to 170 feet, should a maximum flesh occur at a time when the tank may be full. Therefore, in calculating the pressure to be resisted, 170 feet have been taken as the depth. The masonry dam will offer a resistance equal to about twice the force which would be generated by that depth of water, and, in order to increase the stability of the dam, the lower part is shown as carried up vertically for a height of 48 feet, and upon the rear portion, a series of retaining walls will provide for the loading of the rear slope with earth and stones, thus raising the ratio of resistance to between 2·6 and 2·7 to 1. The wall will be composed of stone masonry, brick-work, and concrete, and the weight of a cubic foot has been taken as, on the average, 120 lbs., the weight of a cubic foot of the earth and stone loading has been assumed to be 100 lbs.

The Waste Weir has been designed; but, on visiting the site, it ap-

peared to me that a more detailed examination would be necessary, in order to ascertain the exact position, extent, and quality of the rock which there, on the ridge line, appears above the surface, and the Executive Engineer at once directed the requisite clearance to be made, and trenches to be cut, at intervals of about 100 feet, transversely to the direction of the proposed weir, so that the best position for it as well as the most suitable arrangements for receiving the overfall might be ascertained. The lowest point of the saddle is at 125¼ feet, 160 feet being full tank level. At the low central portion, even should the rock be as well adapted to receive the overfall as has been supposed, a second line of wall will be needed, and this has been provided for. Mr. Gordon estimates the maximum discharge of the river at eight millions of cubic yards per hour, but the weir is intended to provide for a discharge of ten millions, with a depth of 10 feet on the crest, and the length of the latter necessary is therefore, in round numbers, 700 feet.

The Sluices proposed are two sets at the south end of the main dam, each to be capable of discharging 500,000 cubic yards an hour, the sill of the lower set being at 65 feet, and of the upper set 110 feet, above zero. A smaller set is intended to be placed in the waste weir.

For passing summer water and low freshes, during the time of construction of the main dam, five arches are shown in the design, that in the centre has a span of 60 feet, rise 15 feet, thickness of arch 4 feet; the other four arches are of 30 feet span, and are semi-circular with a thickness of 3 feet. The piers are 45 feet thick, and are 30 feet high to the springing. Supposing this arrangement to be adopted, it would be advisable to make the central arch semi-circular, and to increase considerably, perhaps to double, the thickness of all the arches. These arches, after serving their primary purpose during the construction of the dam, may either be blocked up entirely, or sluices may be inserted in them for discharging the lower portion of the tank water; in which case, a sluice platform, at about 90 feet above zero, would be required. The dam itself would need considerable modification, to allow of these deep sluices being worked from the road-way at top.

As before mentioned, the bed of the river, at the gap where the dam is intended to be built, is composed of stratified rock having a nearly vertical dip. This rock evidently forms the axis of the hills, and it reappears on the surface at the waste weir saddle, and presents the same

appearance It varies in character considerably, some of the strata being extremely hard, and others much less so

The waste water, after passing the weir, is to be conducted back to the river by a channel, on the further side of which a training bank is to be thrown up to guide the water until the channel shall have assumed a permanent form. The greater part of the soil over the area between the channel and the hill will be required for the rear slope of the main dam, and for the embankments at the two ends, as also for brick-making Several trial pits have been sunk, and excellent clay either for puddling or for brick-making is obtainable in sufficient quantities for the requirements of the works as designed

The rock in the bed of the river is for the most part not adapted for any other masonry than random rubble, but at about five miles north of Luckawully, an excellent stone for coursed masonry is obtainable. This stone which weighs about 170 lbs. to the cubic foot, and is very compact and close-grained, will, I think, be found well adapted not only for wall work, but for the linings of the sluices, &c

The regular survey of the area within the contour has not as yet been commenced, the survey parties having been engaged on the other sites, where the extent of cultivated land liable to submergence is very much greater than in this case, in which nearly all the area is covered with dense jungle. This being the case, the actual area and capacity have yet to be more accurately determined than can be done from the data already obtained. The estimated area is 20 square miles, and the capacity 1,225 millions of cubic yards.

The information also regarding the discharge of the river is still far from complete One year's observations have been taken since the particulars given in the papers printed in Proceedings of the Madras Government of the 23rd July 1866 were obtained, but the results have not yet been calculated. It will be advisable to register, very carefully, the freshes of the season which will shortly commence, and it is necessary also that the data on which the discharge of a maximum fresh may have been estimated should be very clearly explained, otherwise it will be impracticable to judge whether the dimensions of the waste weir are sufficient It may be noticed that a discharge of eight millions of cubic yards in the twenty-four hours is equivalent to a rain-fall drainage of three inches, which does not seem to be very large as the maximum, from a basin of

760 square miles. However, though this may represent a very much heavier rain-fall, seeing that the greater part of the area is covered with deep vegetable soil, and though the proposed waste works and sluices will discharge about eleven millions instead of eight millions, the actual maximum discharge should be ascertained as accurately as may be possible, by finding out the level reached by the freshes at several points, and connecting this information with cross and longitudinal sections of the river. Works of such magnitude as the reservoirs contemplated by the Company require that every possible precaution should be taken, and this can only be done by obtaining full information on all points on which the arrangements, by which security is to be ensured, must be based; for an accident would not only lead to great pecuniary loss, but would devastate a vast extent of country, and occasion a great sacrifice of life

It has been noticed that the maximum water level with 10 feet going over the waste weir will be 170 feet, and that the level of the road-way over the main dam is 174 The margin will be increased by massive parapets 6 feet high, which will bring the level of the dam up to 180 feet above zero

Estimates for the reservoir have been prepared, and they amount to Rupees 30,97,110, the works and their cost being :—

Main dam	Rupees	27,16,710
Channels from sluices	„	47,100
Waste weir	„	1,93,900
Sluices in do.	„	36,000
Waste water channel	„	1,03,400
		30,97,110

The quantities and descriptions of work in the main dam, with the rates allowed, will afford data for judging of the sufficiency of the estimates, and they are accordingly given as follows :—

The most important items in this estimate are the coursed rubble masonry.—Brick masonry.—Hammer dressed masonry.—Earthwork in embankment.

The rate allowed for the first is Rs. 8-11-6 a cubic yard, and, even supposing that the whole of the material has to be brought, five or six miles, I think the rate would prove sufficient. The stone intended to be employed is found and has been used in many parts of the country, and there is every probability of its being found, therefore, in sufficient

	Quantities	Unit	Description of work	Rate	Amount including contingencies
				RS A. P	RS.
	2,252	C yd	Rock excavation in river, .	2 0 0	11,160
	8,759	,,	Do for wings, &c	1 8 0	
Cubic yards 1,72,914	29,119	,,	Earth excavation,	0 3 6	7,000
at Rupees 8-11-6	46,68,694	C ft	Coursed rubble masonry, ...	0 5 2	16,58,300
	15,729	C yd	Rough rubble masonry, ..	4 13 2	83,450
Cubic yards 34,941 at Rupees 6-3-0	9,43,398	C ft	Brick masonry, .	0 3 8	2,42,400
	2,60,270	,,	Stone arch work,...	0 8 6	1,52,100
Cubic yards 9,633 at Rupees 12-3-9	26,414	,,	Brick do, .	0 4 6	8,170
	2,60,079	,,	Hammer dressed masonry, ...	0 7 8	1,29,680
	11,169	,,	Cut-stone masonry (black stone),	1 2 6	32,710
	8,030½	,,	Do. (granite), ..	1 10 6	
	1,758	,,	Beamstones, &c,..	2 0 0	
	11,104 4,041	,,	Coping string courses, &c, .	0 7 0 0 6 0	7,010
	50,302	C. yd	Concrete filling,...	3 0 0	1,66,000
	81,420	,,	Earth and rubble filling, ..	0 7 0	39,180
	2,80,000	,,	Embankment, west end of dam, ..	0 2 0	1,68,300
	28,000	,,	Do	0 1 3	
	89,469	,,	Do. selected earth for front, ...	0 8 0	
	1,66,244	,,	Do do for rear,	0 5 0	
	9,481½	,,	Stone pitching, .	2 0 0	
	454⅜	,,	Backing to do, ..	0 6 0	
	1,130	Sqrs.	Pointing brick-work with cement,	10 0 0	11,300
					27,16,710

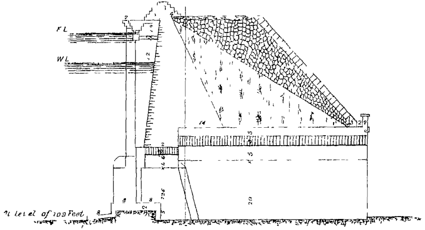
abundance. It is the same as that used for the new sluice at the Masoor tank, and which I at first supposed to be a description of limestone, but Mr Gordon tells me that it does not contain any lime. I have brought a specimen with me, and its composition and character will be ascertained.* For bricks, excellent clay is available in large quantities on the north side of the river, within half a mile of the site for the dam. Wood to burn bricks is to be had in any quantities close at hand, so that Rs. 6-3-0 a cubic yard should suffice for brick masonry. The same stone would be used for the hammer-dressed, as for the coursed rubble, masonry, and the additional rate, Rs. 3-8-3 a cubic yard,

* Quartzite or something between Whinstone and Trap.

LUCKAWULLY RESERVOIR

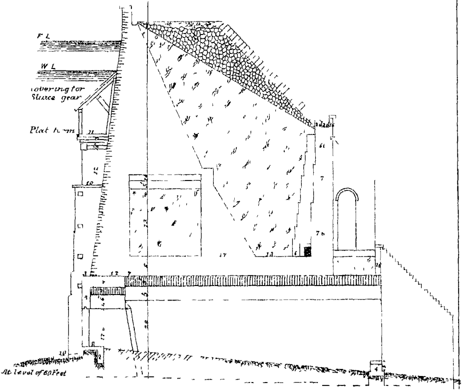
UPPER SLUICE

Cross Section through Vent



LOWER SLUICE

Cross Section through Vent



for the dressing appears to be ample The rate, two annas a cubic yard, for a large proportion of the earth-work in the west embankment is, I think, too low. Probably it will be obtainable most easily from the plain, north east of the dam, and the average lead could hardly average less than 200 yards, seeing that an area of 265 yards square, cut down to a depth of 4 yards, would be necessary to supply the 2,80,000 cubic yards required; soil could be obtained from the hill side, but there the roots of the jungle would interfere greatly with extensive excavations, even were the trees all cleared away. I am therefore inclined to think that the rate for this work should be doubled, which would add Rs. 35,000 or, with contingencies, say Rs 38,890 to the estimate, thus making the total Rs 31,36,000.

The probable value of the reservoir, supposing this estimate to be correct, and assuming the capacity to approximate to 1,225* millions of cubic yards may be stated as follows —To the amount of the estimate must be added charges for permanent establishment, Home and Indian Agencies, &c, which, in accordance with the facts of the Kurnool works, may be taken at somewhat under fifty per cent. The total ultimate cost of the reservoir would then be 45 lacs, and the quantity stored for one rupee would be 272¾ cubic yards It may, looking to the character of the river, be considered that the reservoir will be full at the time when Toombudra freshes begin to run low and require supplementing, and also that, on the average, the river supply will compensate for evaporation † from the surface of the reservoir during the time its supply is being utilized. If then 10,000 cubic yards be taken as the quantity required to be stored to supply one acre of irrigation, the reservoir will, if considered only as an irrigation work, be capable of irrigating 1,22,500 acres, the gross revenue from which, at 6 Rupees an acre, would be Rupees 7,35,000, or 16 per cent. on the outlay. Such being the case, there would be a considerable margin available either for extra cost of works or for the absence of a full utilization of the water. Thus, supposing the works to cost even 60 lacs, and the acreage irrigated not to exceed 80,000 acres, the gross return would still be as much as eight per cent The figures above given may be liable to considerable modification when the information required regarding the capacity of the reservoir, the maximum and total yearly discharge of the river, &c., is obtained; but they tend to show

* This requires an average depth of a little over 20 yards for the area 20 square miles

† This would amount to about 12,000 cubic yards per hour as the maximum.

that, comparatively unfavorable as is the result of the investigations thus far in regard to the quantity of water likely to be stored for each rupee of expenditure, there is every probability of the construction of the Luckawully reservoir proving to be financially desirable

With regard to Mr. Gordon's design, the only point in connection with the main dam which it seems necessary here to notice, is the arrangement of the irrigation sluices at the southern end. It will be seen that training walls conduct the water for a distance of about 170 feet, and the water is then to flow into the river. This arrangement, however, is hardly likely to be economically practicable, unless rock sufficiently hard to stand the wear and tear of the rush of so considerable a body of water should be found with its surface not much below the level of the sluice sills, and thence sloping to the bed of the river. The existence of rock so situated has not been ascertained by sinking shafts down to it, and as, therefore, it is not actually known that rock exists at a level much above the river bed, it is clear that sluices so circumstanced may need a succession of falls below them, and this necessity might make a modification of the arrangements advisable.

The Masoor Tank restoration.—The project for restoring this tank will be ready in a few months. The contour has been completed, and is being worked on the ground; the cross sections have been nearly completed, and the surveys of the cultivated lands are getting on well It is expected that the whole of the field work will be finished by the end of the present working season, or about the 15th of May.

Regarding the discharge of the Choardy, the Executive Engineer has been unable to furnish me with any additional information; but measures have been taken for the registration of the freshes of the next monsoon, and longitudinal and cross sections of the river near Shikarpore have been prepared. The new waste weir, constructed by the Bombay Department of Public Works, will also afford a separate means of observation, and from the two sets of observations it is expected that the discharge of the river during this season will be tolerably well ascertained Besides this, Mr. Gordon will be able to compare the rain-fall and discharge of this river with those of the Toonga and Budra and thus an approximate estimate may be formed of the relation existing between the quantity of water passing down in this year with a given rain fall, and that discharged with any other, or with an average rain-fall. How far the year 1867,

the discharge of the Choardy in which is given in the papers printed in Proceeding of the Madras Government of the 2nd December last, approximated to an average one, is not as yet known, but it is there shown that the maximum discharge per second was 2,419 cubic feet, on the 20th July. This corresponds to a rain-fall drainage of one-sixth of an inch from the whole basin, (540 square miles) passing down in twenty-four hours On the other hand, from flood marks Mr. Gordon estimates the maximum discharge at a little less than 15,000 cubic feet per second, and this, which is equivalent to a rain-fall drainage of $1\frac{1}{6}$ inches, does not appear to be excessive There appears to be no doubt whatever that the tank, as originally constructed, did fill. Mr. Gordon thinks that there is evidence to show that at the time the breach in the west bund, which ruined the tank, occurred, some water went over the main bund, and the Superintendent of the Nuggur Division has traced among the records, claims for remission on account of the submergence of lands beyond the ordinary water-spread of the old tank, which corresponds very closely with that of the proposed restoration The year 1867 was an unfavorable one in the Mysore country generally, and it may be, as Mr Gordon suggests, that when the rain-fall is much under the average, a large proportion of the drainage is stopped by small tanks on the several feeders, while on the contrary, in a better monsoon, the greater part of the difference finds its way to the main river. However, further evidence of the extent of the supply is a matter of great importance, and should be obtained, as far as possible, by direct observation, and be supplemented by deductions from rain-fall registers, and by such information as may be obtainable from the Revenue records of the part of the country in the neighbourhood of the tank.

The plotting of the contour had not been completed when I was at Shikarpore, and the exact area of the water-spread at full tank level (90 feet), and with five feet of water (the maximum intended) going over the waste weir, had not therefore, been ascertained, but from approximation from an inferior contour, the full tank area is estimated at 40 square miles The capacity is similarly expected to be 1,400 millions of cubic yards, and this will be determined as soon as the cross sections shall have been completed.

The Executive Engineer has estimated for the restoration of the tank on two different designs.

First.—By a dam across the present surplus channel above the fall, at

the site of the Bombay Department of Public Works new waste weir, with a waste weir at the present east bund of the old tank.

Second —By a dam and weir combined across the present surplus channel.

The designs were worked out in the order above given. The general character of the first dam will be seen from its cross section. It was intended to have a lower and an upper set of sluices for passing irrigation water, the water from the upper set being allowed to drop through a modified arrangement of the grated fall used in the North-West Provinces. For the surplus work at the east bund, two arrangements were planned. The fall to be overcome between the crest of the waste weir and the bed of the Chôardy, near Soolcotta, would be about 120 feet; and, in addition to the over-fall at the waste weir itself, six masonry falls were planned. The length of the crest of the waste weir was to be 370 feet, and the greatest depth of water passing over it was to be 5 feet. There is a natural line of drainage, in the shape of a small nullah, running in the direction which the surplus water would take if discharged at this point, and the distance from the weir to the Choardy would be 2,600 yards. Such a weir would be capable of discharging 1,992,820 cubic yards per hour, or 14,946 cubic feet per second The cost of surplus works so arranged would be Rs 6,04,660.

The alternative arrangement, while retaining the same design for the weir, omitted the masonry falls in the surplus channel, and contemplated allowing the water to cut down until a sufficiently hard substratum might be reached to prevent further action. The estimated cost of this plan is Rupees 3,67,970. No borings have been made on the line of the channel to ascertain what would probably be its ultimate level at various points, and it is clear that it would be necessary to ascertain this with considerable accuracy, in order that the retrogression of levels near the weir might be effectually guarded against.

The ultimate expense of either of these systems would be very problematical. The maintenance of seven weirs in the first case would, in the absence of rock on which to found them, necessarily entail a considerable expenditure yearly, even if the estimate proved to be approximately correct with regard to the first cost of making them efficient. The second plan would, even were the result of borings altogether satisfactory, certainly require much additional expenditure, above the first

cost of the weir itself, for rendering its tail secure, and for preventing the deepening of the bed up to such a distance below as would ensure freedom from leakage through the sub-soil on which the present bund stands. Mr Gordon thinks that there is rock between the hills connected by that bund, and if so, it may be of such an extent and character as to make the construction of a weir here practicable at a moderate expense, but the surplus water could not be allowed to cut its own channel below the weir, unless it were first clearly ascertained that the rock under and below the weir would not be liable to injury either by undermining or by the effects of the over-fall, even were the channel lower down to cut away to the greatest depth which borings might show to be possible.

The cost of the masonry dam, in connection with either of the above waste weirs, would be Rupees 8,47,550. The proposed expenditure on the old main bund is Rupees 91,600, so that the cost of the project on the first plan would be Rupees 15,43,810, and on the second plan Rupees 13,07,120.

The difficulties attending an arrangement for the discharge of surplus water at the east bund having thus been found to be very considerable, Mr. Gordon turned his attention to framing a design for a dam at the present surplus channel, which should serve both for retaining the tank water to the necessary level, and for discharging whatever surplus might thereafter be received. The general features of this arrangement are as follow :—

At about 190 feet below the point, where the Bombay Irrigation Department have constructed a dam-wall across the surplus channel, is the ledge or reef of rock over which the river falls some 30 feet into a basin in the rocks below. On this reef it is proposed to build a dam-wall having a length of 150 feet, a top width of 5 feet, and its crest at 14 feet above datum * In this dam there are to be six sluices, 3 feet by 5 feet, for the regulation of the discharge when necessary. At a distance of 60 feet above the lower edge of this weir is a second or intermediate dam, having its crest 33 feet above datum, and having, in its body, seven sluice vents of 4 feet by 9 feet each. The length of the crest of this dam is to be 209 feet, and the maximum depth passing over would be 8·56 feet. The water passing over this dam would fall into a basin with a hard rock bottom, over which there would be a minimum depth of 12 to 14 feet, and to a maximum of $24\frac{3}{4}$ feet; 145 feet above the intermediate, will be,

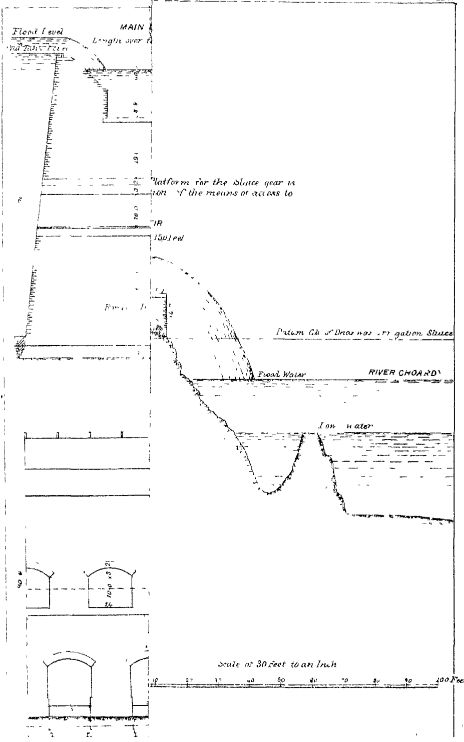
* Sill of new sluice in old main bund

according to this design, the main dam, having a width at base of 70 feet, with its crest arranged in two falls, the upper at a level of $87\frac{1}{2}$ feet above datum, with posts $2\frac{1}{2}$ feet high, and the lower at $77\frac{1}{2}$ feet, with a water cushion having a minimum depth of 9 and a maximum of 15 feet From the second crest, the over-fall will be 46 feet to the level of the crest of the second dam, and the minimum depth of water to receive the fall will be 33 feet, and the maximum 41 56 feet.

It appears to me that the arrangement just described is altogether preferable to that by which the surplus water would be discharged at the east bund. In either case, the water has to be lowered the same depth, viz, the difference between full tank level and the bed of the Choardy; while in the one case, there is rock, the quality of which is known, and which has stood the wear and tear of the whole discharge for many years, and in the other, there can be at best only untried rock, and it is doubtful whether anything harder than partially decomposed granitic rock would be found at all The difference of expense, though important, is nevertheless a secondary consideration, it being of the first consequence to obtain a safe design, and, in my opinion, the system of divided falls with water cushions is not only the safer after the completion of the whole works, but it admits of the works during construction being carried on without any serious risk The third or lowest dam may be built first and the others can be raised successively, just so fast as circumstances may dictate; and a fresh in excess of the capacity of the sluices might pass over the walls at any stage of their progress without occasioning any damage of consequence

The small dam on the edge of the falls could be completed in a few months, and there need, I think, be no doubt of its stability, as the over-fall will be received into a basin of considerable depth, and the rock there having stood an over-fall of 30 feet for a great number of years, would probably not be affected by the additional height 11 feet, of the proposed over-fall to an extent which would be likely to undermine the dam, though it is very possible that the pool may be somewhat deepened. There would be time before damage had become imminent to provide a remedy, and this remedy would be simple and inexpensive, as the most that would be necessary would be the reduction of the fall within safe limits by the construction of another wall across the pool below the third dam

The security of the intermediate and main dams will depend mainly on


Flood Level
MAIN
Platform for the Sluice gear
the means of access to
Flood Water
RIVER CHOARD
Low water
Scale of 30 feet to an Inch
10
20
30
40
50
60
70
80
90
100 Feet

the depth of water in the basins below them, and the depths provided by Mr Gordon appear to be sufficient By the formula $D = 1.5 \sqrt{h} \times \sqrt[3]{d} = 1.5 \sqrt{43.5} \times \sqrt[3]{6} = 17.98$, used for water cushions of vertical falls in the North Western Provinces, the depth of the cushion of the greater fall would, for brick-work, be 17.98 feet, while that allowed here with a hard rock bottom is 33 feet, or perhaps more correctly 35.86. Similarly, below the second dam, the cushion required by the formula would be 12.54 feet, and that proposed is 16.19 feet. I have quoted this formula $1.5 \sqrt{16.81} \times \sqrt[3]{8.56}$, because it has, I believe, been successfully applied to the falls on some of the canals in the North West, but I do not know on what principle it is based. It perhaps errs in giving too small a depth of cushion for high falls. The extreme example of proportion between cushion and fall, with which I am acquainted, is that of the Rajah fall at Gairsoppa, the height of which is 829 feet, and the depth of the pool 130 feet. I do not know what the maximum depth going over would be, but I think not more than 15 feet, making the depth of cushion for brick-work, according to the formula, $1{\cdot}5 \sqrt{829} \times \sqrt[3]{15}$ 107·95 feet, which is too little by about one-fourth—for stone masonry, to which rock would more nearly approximate, the depth of cushion allowed by the formula would for the same fall be 71.97 feet, or not much more than half the actual depth at the Rajah fall.

A great advantage of this system would be, under the circumstances of the site, that it is not likely that any expensive additions will be needed to supplement the works as originally carried out. The existing rock and the water will, between them, absorb the forces generated, and the artificial dams will be subjected to nothing more than the wear and tear of the body wall of an anicut, which is nearly always inconsiderable.

In order, however, to secure the satisfactory action of the water cushions, it is essential that the sluices in the several dams be fully under command, in order that the first and second basins may always be full when any water begins to pass over either the main or intermediate dam. All the sluices should, therefore, be capable of being worked at all times, and this can only be done by placing the gear connected with them on platforms above the maximum level of the water.

I should be disposed to omit the posts on the first crest of the main dam, and to put the sluices which will be needed for the discharge of irrigation water at the two ends, where their platforms, which must be above the 95

feet level, will not interfere with the crest of the weir. The lower sluices should be at the base of the dam, for it would be much better to place them here, than to give additional low level sluices in the old main bund. A second set might be placed about 30 feet above datum, but as, by means of the intermediate dam, the lower set could always be worked under a head not exceeding 57 feet, and as this gives a pressure of less than two atmospheres, there would be no difficulty whatever in providing suitable gear for regulating openings of 3 to 3½ feet in diameter.

The section of the two crests of the main dam might also be altered with advantage, so as to bring the rear edge of the crest to the face of a vertical, or nearly vertical, wall—the width of the water-cushion can be somewhat widened, and the floor should be an invert with a sufficiently high versed sine to prevent the possibility of the displacement of any of its stones.

The estimated cost of the dam with water-cushions is Rs. 7,75,462, and probably, after making such modifications as will tend to secure its entire efficiency, the estimate will not exceed nine lacs.

The proposed expenditure on the old main bund amounts to Rs. 91,600, and provides for raising the earthworks, where necessary, to 108 feet above datum, and for completing and raising the revetment to the 101 feet level. I think, however, it will not be prudent to rely on this old bund being water-tight. Probably it is so, and its enormous thickness (about 1,000 feet), makes it unlikely that any of those causes, such as rat-holes, faults from settlements, &c., which commonly lead to leakage, can exist to a prejudicial extent. Still all risk should be avoided, and I would, therefore, place a thick wall of puddle behind the revetment. As, however, the interior slope of the bank is every where flat, and in some places as flat, as 1 in 5, the puddle would have to be arranged in steps, and in this manner it could be inserted without necessitating the removal of any very great quantity of the old soil. The minimum depth of rammed soil between the puddle and the revetment might be 4 feet. The width or thickness of the puddle at base 25 feet, and, at the 96 feet level, 8 feet. The head of the existing sluices will have to be carefully secured.

The financial merits of this project cannot of course be accurately ascertained, until present deficiencies of information shall have been remedied. The subjoined estimates, however, will give some idea, and I

hope one not too sanguine, of the probable results of the restoration of the tank.

The masonry dam may be taken as likely to cost,		9 lacs
Estimate for old main bund, ...	91,600	
Add for puddle, say, ...	48,000	
Ditto securing sluice heads, ...	10,400	
		$1\frac{1}{2}$ lacs.
Home and Indian Agency and Permanent Establishments, ...		$4\frac{1}{2}$ lacs.
Total, ..		15 lacs.

Next, with regard to the probable supply, Lieutenant Smith of the Bombay Department of Public Works estimates the discharge of the Choardy in 1867 at cubic yards 276,454,400 * The area of the drainage basin is from 1,500 to 1,600 millions of square yards, so that the above discharge represents a rain-fall drainage of about $6\frac{1}{4}$ inches during the year. To fill the tank, a drainage of, in round numbers, 36 inches is required, and I do not myself think that this will be received except in very favorable years, for the Choardy basin, though well within the south-west monsoon, is very differently circumstanced to the upper parts of the Toonga and Budra. The average supply may perhaps be the equivalent of 20 inches of drainage, or say 800 millions of cubic yards. The irrigation under the tank and river in the Bombay Presidency in 1866-67 was not very extensive, (180 Acres) but it appears to be expected that this area will be extended sufficiently to absorb 110 cubic feet per second, and this is stated to be enough for $50 \times 110 = 5{,}500$ acres of rice throughout the year, which may be put, as regards total quantity of water required, as equivalent to 13,000 acres for a single crop Allowing 10,000 cubic yards as the storage for one acre, the Bombay Irrigation would absorb 130 millions of cubic yards, 150 millions will, therefore, be taken as the quantity for which the Company would obtain no returns. Evaporation will, as regards this reservoir, be a not unimportant item. The area of the tank, when containing the average supply (800 millions cubic yards) will probably be about 28 square miles. The average area from which evaporation will take place during six months may be assumed to be 16 square miles, or 48 millions of square yards, and at one-fourth of an inch per

* Cubic feet 7,464,308,800, which however appears to require correction to 7,464,268,800

them the quantity evaporated in the six months will be, in round numbers, 150 millions of cubic yards

It appears then that the average quantity of stored water which will be available annually for transmission to the Company's canals, under the Toombudra, will be about 500 millions of cubic yards, or enough for 50,000 acres. The gross returns, therefore, at 6 Rupees an acre, would be 3 lacs or 20 per cent on the supposed outlay, 15 lacs, required for the carrying out of the project

I have been obliged to calculate the value of the water stored in terms of the area capable of irrigation thereby, this being the readiest and most intelligible way of expressing it , but it is very probable that, should the Company construct these reservoirs, a good deal of the water will not be so utilized, but will be used for maintaining navigation throughout the year on the Kurnool Main Canal, and on any other canals which may hereafter be constructed I have, however, little doubt that, except for the very short time in each year during which there will be no cultivation going on any where, there will ultimately be but very little water which will not be employed in rendering cultivation secure, as well as for navigation. Fully to develope the Kurnool works, somewhere about 600,000 cubic yards an hour for six months need to be provided by storage, and the total quantity would, therefore, be 2,592 millions of cubic yards, or say 2,600 millions Nothing but experience will afford entirely safe grounds for estimating the value of large reservoirs, but the circumstances of the Company's Kurnool Canal appear to me to offer a particularly favorable opportunity for ascertaining that value, seeing that it requires no elaborate argument to show that a perennial, or nearly continuous, water-supply, with the 2nd crops, and more efficient navigation, therefrom attainable, would not only increase the revenue largely, but reduce the relative cost of maintenance in almost direct proportion to the increase of receipts. It is indeed not improbable that it would be worth while to expend half the cost of the Kurnool Main Canal, which for present purposes may be supposed to be 160 lacs, in the attainment of this object. The Masoor reservoir project is from its comparatively moderate dimensions and estimated cost, better fitted than any other, which has thus far been brought under notice, for a first experiment, and I hope it will be so brought forward by the Company as to leave no important point, upon which information can be obtained, in doubt.

No. CCXLII.

PROJECT FOR CHEAP NAVIGATION CANALS.

A plan for the construction of Steam-boat Canals, the water for lockage and evaporation being raised by steam-power. By LIEUT.-GENERAL SIR A. COTTON, K.C.B., R.E.—*Dated 23rd June, 1868.*

In 1858 I was ordered by the Government of India to proceed to Cuttack, to report upon the state of the Mahanuddee at that city,* and the Lieutenant Governor of Bengal took the opportunity to obtain the authority of the Viceroy for my inspecting the country between the Hooghly and the main Ganges, in order to project a work for the constant communication by water on that line, the present direct communication by the three Rivers, the Matabhanga, Jellinghee, and Bhagiruttee, being only available three months in the year, on account of the insufficiency of the water in them when the Ganges is low. For the rest of the year, the steamers have to go down the Hooghly to the sea, and through the Sunderbunds to the Ganges, a detour of 300 miles

I had the honor of furnishing the Government of Bengal with a project for this purpose, the works consisting of a Weir across the Ganges at Rajmahal, similar to those at Madras, with a Canal for both irrigation and navigation, thence to Calcutta, 180 miles. This, I have no doubt, will be a most beneficial and highly remunerative work.

I understand a work of this kind is now under consideration.

* *See* No. LXXXVII. of these Papers.

But circumstances have lately arisen which have forced this question of navigation in Bengal upon me, and have led to the discovery of a mode of accomplishing this object of navigation alone, so cheaply, that had it occurred to me at that time, I should have probably proposed a project of much smaller extent, and which it is extremely probable would have even then been carried out, as Lord Canning was Viceroy at that time.

This matter has been brought before me now by the late Report of the Orissa Irrigation Company, in which the extraordinary returns received on their navigable canals have shown the immense demands for such works, and their consequently highly remunerative character

On their tidal canal between the Hooghly and Midnapoor, they have now opened only about 25 miles, and of this only the first portion of 8 miles was used to any extent, and though it was so short, and ended at no place of the smallest importance, there was a traffic of no less than 8,300 boats in the last-half of last year, carrying 57,000 tons and 30,000 passengers, paying £736, or about £80 a mile, equal to £160 per annum; and, as in the first three months of 1868, the tolls were three times that of the corresponding period of 1867, so also on the 26 miles of canal leading towards Cuttack, and also ending at only a small town, and the work in a very incomplete state, the tolls were £946, or £36 a mile, equal to £72 per annum, while the previous year they were only £397. If there is such a traffic on such small portions of canal, not completing the communication with any important point, with such a rapid increase in a single year, it is certain that when these two lines are completed, the one to Midnapore, and the other to Cuttack, putting the whole Delta and the Upper Mahanuddee in direct communication with Calcutta, the tolls will be many times these amounts.

If the tolls are no less than £160 a mile on a small portion of the line to Midnapoor, and £72 a mile on the first 26 miles towards Cuttack already, and increasing 2½ and 3-fold in a single year, we may be certain that when these lines are completed, the tolls will be at least £300 or £400 a mile, which, on the 50 miles of canal to Midnapoor, and the 250 to Cuttack, would be about £100,000, or 10 per cent. gross, an ample return on the whole present capital of the Company.

From this it seems certain that as they will have at least 500 miles

of main canal when they have completed their first set of works, costing about £1,300,000, the navigation alone will provide a high interest independent of any irrigation returns

But it is certain that the traffic on this side of Calcutta must be only one-fifth or one-tenth part of what there is on the other side leading to the main Ganges and the Berhampooter The tonnage of the boats entering, and the same leaving, the Circular Canal at Calcutta, was several years ago 3 million tons, and it must be rapidly increasing, and were there a constant communication with the Ganges by an effective steam-boat canal throughout the year, this alone would certainly add enormously to the traffic, so that we could not reckon upon less than 2 or 3 million tons and passengers per annum on such a line.

These great and astonishing results already obtained on the short canals of the Company, have led me to re-examine the whole subject of water communication in Bengal, and this is what has led to a most important discovery in the matter in a point which entirely escaped my notice when I was ordered upon that duty in 1853. At that time it never occurred to me to calculate *what would be the cost of raising water by steam-power to re-place that lost by lockage and evaporation in a canal carried upon a high level* But I have now done this, and find that the cost is altogether insignificant, so that a canal may be carried upon any level that will give the least possible excavation.

I have, therefore, now the honor of submitting the accompanying Memorandum on this subject

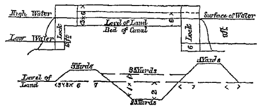
This investigation shows conclusively that canals may be cut in any direction in Bengal at a cost quite trifling, fitted for large steamers, and at any speed, at about £500 or £600 a mile. And not only in Bengal, but as the cost of raising the water is so small, that even a lift of 50 feet would be no obstacle, such canals might be cut on any part of the Plains of the Ganges, or in other tracts of India, each individual canal of 30, 50, or 100 miles connecting important points, being a complete project in itself, quite independent of any extended scheme. This puts the whole question of steam-boat communication over a great part of India on an entirely new footing, as most important lines *might be opened in a few months*, costing from £10,000 to £50,000 each, paying any interest that might be required. For instance, had this point occurred to me in 1859, I should probably have

proposed a simple work of this sort from Calcutta to a point in the direction of the main Ganges, where it would meet a branch river that is always open,—a distance of 100 miles, costing at most £50,000, which could have been cut by 10,000 men in about six months, conveying a traffic of at least 2 million tons, and yielding, at a toll of $\frac{1}{8}$th penny per mile, or £2,000 a mile per annum.

I therefore beg to submit this plan for steam boat canals as worthy of thorough consideration

The fundamental question with respect to navigation canals in Bengal, and, indeed, throughout the Plains of the Ganges, and in other Plains of India, is, *what is the cost of re-placing the water consumed in lockage and evaporation by raising it by steam-power?* If this cost is found to be insignificant, then, instead of a deep cutting for the canal in order to be able to admit water from the river or creek, it will only be necessary to cut a single yard, or so deep as just to obtain earth enough to form an embankment on each side, so as to give a sufficient depth of water, part of the water being below the level of the surface of the ground, and part above it, and the excavation will be simply in dry earth, and the quantity for a broad canal very small.

The longitudinal and cross-section of the canal might be then as shown here—



Excavation banks $7\frac{1}{2}$ yards $\times$ 2 $\times$ 2 = 30 yards, 30 $\times$ 1,760 = 53,000 cubic yards, @ $1\frac{1}{2}d.$ = £330 per mile.

This would give a canal 35 yards broad at the top, and 23 yards at the bottom.

In such a canal, the water in it would be $4\frac{1}{2}$ feet above high-water, and $13\frac{1}{2}$ above low-water, or the average lift, if the engine was worked throughout the day, 9 feet. If the locks were 150 feet long, 15 feet broad, with an average lift of 9 feet, the contents would be 750 cubic

yards of water, weighing, at 1,700 lbs per cubic yard, about $1\frac{3}{4}$ million lbs—to be raised 9 feet, $= 13\frac{1}{2}$ millions, 1 foot; or about 8 Indicator H P for 1 hour, or three nominal H P for 1 hour, and the cost would be at 3 lbs of coal per I H P at Rs. 10 per ton, $\frac{1}{3}d$, or adding for management, &c, about $\frac{1}{2}d$ per I H P. per hour. This would give $4d$ per lockfull Locks of this size would pass boats of at least 200 tons, and if the canal were 50 miles long from one creek to another, 10,000 tons would be carried 1 mile for every lockfull, so that the cost for supplying the lockage would be $\frac{1}{2500}d$ per ton per mile, in fact, insignificant

On the same canal, the evaporation, allowing 2 yards per annum, or $\frac{1}{5}$-inch per day above rain-fall, would be 1,760 yards $\times$ 2 yards $\times$ 35 yards $\times$ 50 miles $\times$ 1,700 lbs. $=$ 10,500 millions, lbs. to be raised 9 feet, $=$ 95,000 million lbs, 1 foot $=$ 60,000 I H P. per 1 hour, costing @ $\frac{1}{2}d$ per I H. P, £125 per annum, and if the traffic were 1 million tons and passengers a year, equal to 50 millions through 1 mile, the cost of supplying water for evaporation would be $\frac{£125}{50 \text{ millions}} = \frac{1}{1700}d$ per ton and per passenger per mile.

This also would be quite insignificant, the two together being only $\frac{1}{1000}d$.

We arrive, therefore, at this remarkable conclusion, that the cost of raising the water is in effect nothing, leaving us to cut the canal on any level that will give a minimum excavation. And even if the water had to be raised 50 feet out of deep rivers or wells, it would still be only $\frac{1}{250}d$ per ton per mile.

It may be asked,—but what about absorption? To this I reply that in these alluvial soils, there would be none at all; but even if it were very considerable and permanently so, even an inch a day, it would still only raise the cost to $\frac{1}{400}d$ The cost of locks on such a canal would be, at £200 per foot of lift, $13\frac{1}{2} \times 200 =$ £2,700, or £5,400 for one at each end, adding £100 per mile. If we allow 50 yards of aqueduct for crossing small creeks or streams in the 50 miles at £100 per yard of length, this would add £100 per mile, and the estimate would then be per mile—

	£
Excavation, ...	330
Locks, ...	110
Aqueduct, ...	100

or £540 a mile for a canal 35 yards broad and 2 yards deep.

The cost of engine-power and apparatus would be trifling, as an engine of 10 nominal H. P. working by day only would be sufficient, costing about £500, or £20 per mile. Such an engine would take about a month to fill the canal in the first instance, but the canal would be available of course as soon as it had 2 or 3 feet of water in it.

The returns on such a canal on an important line in the neighbourhood of Calcutta, allowing only 1 million tons and passengers, or 500,000 of the former at $\frac{1}{8}d.$, and the same of the latter (1,600 passengers per day) at $\frac{1}{16}d.$, would be £380 per annum, or 65 per cent. on £560 a mile. But on the main line connecting Calcutta with the Ganges, the traffic would be at least 2 millions, for the tonnage of boats alone entering the Circular Canal, several years ago, was 3 millions, and of course the same boats left it, and this is besides all that discharged and loaded in the Hooghly.

And this plan is equally applicable to the upper plains of the Ganges, because the cost of raising is so small, that even where the ground is 40 feet above the summer level of the river, it would still be an insignificant item. To make a navigable canal to be supplied from the river in such a case, without raising the water, would involve a weir, which would be a heavy work, and would, perhaps, take two years to build where the river is wide, besides heavy cutting at the head of the canal; but if the water is raised, the canal would be formed as near the sea, by a simple cutting of a yard or so deep. Thus, a straight steam-boat canal might be substituted for the winding river with its strong current in the monsoon, and its shallows in the dry season from Allahabad to Benares, reducing the cost of transit to quite a nominal sum, and the time, from several days as it often is in the dry season, to a few hours.

This line of 80 miles would involve about 100 feet of lockage in all at £200 a foot, or £20,000, and 50 nominal H. P. of engine costing about £2,500, or with £350 per mile for excavation, about £650 per mile in all. The toll required to pay the interest of this capital at 7 per cent., including repairs, would be $\frac{1}{8}d.$ on only 90,000 tons a year, and a million tons would yield a return of £500 a mile (80 per cent.) with that toll.

These plain calculations seem quite sufficient to show the great importance of this point, and the wonderful opening it makes for providing steam-boat navigation over a great part of India at a trifling cost

in a very short time, and with very great money returns, a single million would probably provide 2,000 miles of first class steam-boat canal, yielding at least half a million a year, and the works might easily be executed in a single year

On any line in which so wide a canal, as the above sections show, was not required, a considerably less section and excavation would be sufficient, as it might be made deeper and narrower, and the embankments lower, for instance, $1\frac{1}{2}$ yard of the depth of water might be carried below the surface of the land, and $\frac{1}{2}$ yard above, making the embankments only $1\frac{1}{2}$ yard high, with a section of only 9 square yards each costing only £200 a mile for excavation

CCXLIII.

KURRACHEE HARBOUR WORKS.

To the Editor.

DEAR SIR,

I have the pleasure to transmit herewith a copy of "Memoir on Kurrachee Harbour" by Mr W Parkes, C E., printed under authority of the Secretary of State for India, and for which I would hope that you may be able to find room in an early number of the "Indian Engineering Papers," as giving the latest resumé of the Kurrachee Harbour Works question, regarding which some papers appeared in your Number for February, 1868.*

The question may be said to have all the more interest for the profession, as active operations have been resumed

About 10,000 tons of the rubble base of the Breakwater will have been deposited this season, and the improvement of the West channel, partly by dredging and partly by natural scour, is being found very valuable to navigation.

Yours very truly.

W. H. PRICE,

M Inst. C E.,

Supdt., Kurrachee Harbour Works.

MANORA, KURRACHEE,
20th May, 1869.

Memorandum by W. PARKES, ESQ., M INST. C E., *Consulting Engineer for the Harbour Improvement Works.*

THE papers on the Kurrachee Harbour Works have become so voluminous as to render it difficult for any one not familiarly acquainted with the subject to obtain a connected idea of their history. While dis-

* *See* No. CLXXV. of these Papers

puted questions remains undetermined by the Government, the *resumés* of the whole subject which were put forth, almost necessarily either bore the character of *ex parte* statements, or, if impartiality was aimed at, the attempt to present the conflicting views in a concise form resulted only in confusion and unintentional misrepresentation of one or both sides.

Now, however, that the Government has decided on carrying out the policy with which I have been identified, a sketch of the whole subject from my point of view can hardly be considered as *ex parte* in an objectionable sense. The sketch would be manifestly incomplete without allusion to the proceedings and objections which have served for so many years to retard the prosecution of the undertaking, but in alluding to them now, it is unnecessary for me to attempt to present the views of those who differ from me as consistent wholes My only concern is with those parts which especially conflicted with the principles of the positive recommendations made either by Mr. Walker or myself I trust I have not *misrepresented* any one, but I make no pretence to have given a complete view of principles in which I do not concur. I may further add that I have not thought it necessary or desirable to confine myself to such views of certain parts of the subject as the Government as a body, and still less, individual members of the Government, may be prepared to endorse.

The late Mr. James Walker was first consulted as to the improvement of the harbour of Kurrachee in the year 1856, and he made a preliminary report on the 8th September of that year

The opinions expressed in that report were based on a survey then recently completed by Lieutenant Grieve, I.N., and on information furnished by several gentlemen acquainted with the locality then in England. Mr. Walker's conclusion was that, through the application of proper means, the "deepening or even entire removal of the bar and the general improvement of the harbour" might certainly be accomplished.

Rather by way of illustration than as pledging himself to any particular plan, he suggested a system of works which he thought would be suitable for the purpose. He at the same time recommended that an engineer should be sent out to make the necessary surveys and examinations on the spot, and report to him previous to his making a complete design

I was appointed to this service, on Mr. Walker's recommendation, by the Court of Directors of the East India Company in the latter part of 1857, and after spending five months at Kurrachee, I returned to England and reported to Mr Walker in June 1858.

Mr. Walker's second report, with which mine to him was combined, was made in October of that year. In it he confirmed the general principles which he had laid down in his former report, and repeated his recommendations as to the works to be executed, with little variations from his original suggestions. Those works, which are shown on the accompanying plan, were, shortly, as under —

1. A breakwater in a direction S. by E. for 1,500 feet from Manora Point (Estimate £110,000)

2. A stone bank or groyne from the western end of Keamaree Island to opposite Manora Point, so as to confine the whole of the ebbing and flowing waters to the main channel of the harbour for a length of about two miles, and the entrance to a width of about 2,000 feet. (Estimate £42,000, and east pier extension, if required, £40,000.)

3. The diversion of the tidal water which ebbed and flowed through the Chinna Creek into the harbour itself, by closing the creek (£9,000); removing a portion of the Napier Mole, and carrying a bridge on piles over the opening (£40,000), excavating a channel into which the tide waters would be collected and conducted into the harbour (£18,000) and the formation of a jetty ("Native Jetty"), for further guiding them, which would be also used for wharfage (£28,000, or for the whole of this series of works, £95,000)

Thus the estimate for the improvement of the harbour (exclusive of docks and basins, for which Mr Walker indicated the best sites and arrangements) was, in round numbers, £300,000.

As the result of these works, Mr. Walker anticipated that a depth of at least 20 feet at low water of spring tides, giving 29 feet at high water of spring tides, and 25 feet at that of neap tides, with ample width for navigation sheltered from the worst winds, might be depended on.

The groyne, besides bringing the whole scouring power of the harbour to bear upon the entrance, was also calculated to enlarge and improve the anchorage, and the diversion of the Chinna Creek waters, besides further increasing the scour on the entrance, would form and

maintain a channel of sufficient capacity for the passage of the largest native craft up to the proposed new jetty near the town and the offices and warehouses of the merchants.

It is worthy of remark that although Mr Walker's proposals have been met by strong opposition from many quarters, and every detail has been subjected to the severest criticism, only one specific proposal of any other system of improvement (that of Lieutenant Taylor, I.N. in 1860) has since been made, and that has not been pressed.

Thus, the only recommendation ever prominently brought before the Government or the public, has been to carry out Mr Walker's plans in their integrity. All the opposition has been of a negative character. No one has denied the capability of the harbour for improvement, no one (with the one exception above named) has proposed any plan of improvement to supersede Mr. Walker's. Nor, it may be added, have the close observations of local phenomena and changes which have been made, both by supporters and opponents of the works during eight years, resulted in the establishment of any fact which suggests material modification from the details of the plan as originally designed I am aware that this statement may appear inconsistent with the existence of the strenuous opposition led by General Tremenheere, but a careful examination of the papers will show that that opposition is entirely of the above negative character. The policy of improving Kurrachee Harbour at all therefore is, by the absence of any other proposal, identified with Mr. Walker's plans for accomplishing it. This ought to afford a strong presumption in favour of the general soundness and comprehensive character of his views

Mr. Walker's plans, submitted, as above stated, in October 1858, having been considered by the Government, it was decided on financial grounds that it was undesirable to give immediate sanction to the expenditure of so large a sum as £300,000, and it was therefore determined, with the very qualified and reluctant concurrence of Mr. Walker, to defer the sanction of the execution of the Manora Breakwater. He afterwards (in April 1861) took an opportunity of formally expressing his regret at this decision.

In February 1859, then, the Keamaree Groyne and the system of works connected with the diversion of the Chinna Creek waters, at an aggregate estimated cost of £137,000, were sanctioned. It was decided

to place their execution in charge of the officers of the Public Works Department, under the general superintendence of Colonel Turner, R E, then Chief Engineer in Sind, and who, having been in England and having frequently conferred with Mr. Walker during the preparation of the design, concurred in his recommendations. Mr. Walker, however, had further recommended that tenders for the execution of the whole of the sanctioned works should be asked for from responsible contractors, but this recommendation was not adopted.

Colonel Turner, however, appears to have had the intention of making a local contract for the whole of the works, for, at his request, Mr Walker prepared for him detailed plans and specifications with a view to such a contract.

It should be stated that I took no part in the preparation of these plans and specifications, considering that the engineer who was to have local charge of the works should have the sole responsibility in their adaptation to local circumstances.

No contract was ever based upon these plans and specification, but the works were from the first carried on departmentally, and the specification used as a code of instructions to the engineers in charge, a purpose for which it was not intended or adapted.

With the exception of a reply to a reference to him of Lieutenant Taylor's scheme in 1861, the preparation of these plans and specification was the last service which Mr. Walker or his firm performed in connexion with Kurrachee Harbour. He died in October 1862.

Orders were given for the commencement of the works early in 1860, Mr. Price, C.E., having been appointed superintendent, under the general direction and control of Colonel Turner, Chief Engineer in Sind. In May 1861, Colonel Turner was succeeded by Colonel Tremenheere, so that the works had not made sufficient progress to show material results before his connexion with them ceased. Colonel Tremenheere from the first took an unfavourable view of Mr. Walker's plans, both in their principles and in every detail, and persistently urged their abandonment upon the Government.

In the early part of 1862, a revised estimate was made of the probable cost of the works as they were being executed on the departmental system, the amount of which was very much in excess of that of Mr. Walker's. In the absence of explanation this result appeared to tell

unfavorably against either the sufficiency of the original estimate or the economy of the execution.

Much of this discrepancy, however, was in fact due to misapplication and misunderstanding of the plans and specification which Mr Walker had furnished to Colonel Turner, arising from a want of communication between Mr. Walker and the engineers in charge, while the works were in progress. A considerable economy was ultimately made upon the revised estimates, but the greater part of the unnecessary expenditure had been incurred before the character of it was pointed out. These remarks apply only to the Napier Mole Bridge, Native Jetty, and New Channel, which (estimated originally at £86,000) have cost £170,000. The Keamaree Groyne and East Pier, so far as executed, have cost less than the estimate. The details of the works themselves were executed with every regard to economy and reflect much credit on the engineers in charge

The Keamaree Groyne was commenced in November 1861, and was completed in April 1863, to the length included in the intended contract viz, about a mile and half. There were no special physical reasons for the termination of the groyne at this particular length. It was no doubt assumed that before that length should have been completed, new materials for deciding the questions of its extension and of the principles of its construction at the outer end would have been collected, and that, if an extension should appear desirable, it would be proceeded with without interruption. Mr. Price did, in fact, recommend such an extension early in 1863, and his recommendation was supported by General Scott, Chief Engineer of the Bombay Presidency, but being opposed by Coloned Tremenheere, it was not prominently brought before the Government

About the same time, that is in 1863, the works necessary for the diversion of the Chinna Creek waters were so far advanced that preparations were made for closing the creek and removing the dam which separates the Chinna Creek marsh from that of the harbour.

Such was the state of the undertaking when in October 1863 I was instructed by the Secretary of State, at the request of the Bombay Government, to give my opinion whether any of the facts noticed by Colonel Tremenheere in certain reports made by him to the Government "rendered a change in any part of the plans of the harbour works advisable."

The facts so brought to my notice were the effects produced by the action of the groyne upon the scour of the harbour, as shown by surveys made in January and April 1863. Those effects may be described, shortly, as follows —

1. A very large quantity of sand ($23\frac{1}{2}$ millions of cubic feet) had been washed out from the harbour channel, thereby increasing the water space of that portion of the harbour about 9 per cent But of the sand so washed out, a portion, though a very small one, had been deposited in the line of navigation between the end of the groyne and the sea Moreover, the action of the scour extending to the bar at the entrance, which consisted of a very fine light sand, had completely deranged the form of equilibrium which the contending actions of the scour of the tidal waters in their original volume, and the surf raised by the south-west monsoons, had impressed upon the material of the bar Portions which were formerely deep had been filled up, while other parts had been lowered. The effect on the whole was encouraging as to the ultimately beneficial action of the increased scour, which had already carried so large a quantity of sand clear away to sea, but the immediate effect was injurious to the navigation of the entrance.

In view of these facts, I expressed a confident opinion that the actually injurious action was only temporary, and that the evil would cure itself, but that, as to any recommendations for further works which might be advisable for reducing the temporary evil to a minimum, or obtaining the maximum of ultimate advantage, I wished, before making them, to see what had been the effect of the monsoon then just over. My definite recommendations, therefore, were confined to one point, viz.; that the diversion of the Chinna Creek waters, then about to be carried out, should be postponed. I advised this in the belief that the temporary evil then affecting the entrance was due to an excess of scour too hastily thrown into the channel, and that a further addition of scour, in the then condition of the entrance, would aggravate the evil. At a future time, when the channel should have recovered itself, and with certain precautions, I considered that the diversion might be carried out with much advantage.

Shortly after the delivery of this report, I was instructed to visit Kurrachee, and, after making a full investigation into the whole subject, to report to the Bombay Government.

With this view I arrived at Kurrachee early in January 1864, and remained there for two months. I had then the advantage of meeting Colonel Tremenheere, and of discussing the whole question with him. I informed him unreservedly of all my conclusions, and he did the same to me except upon one point, which he afterwards brought very prominently forward, and which gave rise to much correspondence

The effects produced during the monsoon were principally the following —

1st. The characteristic form of the bar was restored, a high bank of sand being piled up as a barrier immediately in front of the entrance, while the circuitous channel round the tail of this bank was re-opened to the same depth as formerly, but to a less width (and consequently less depth available for navigation).

2nd. A considerable quantity of sand was washed into the harbour channel, partially replacing that which had been washed out previous to the monsoon.

In view of these facts, I repeated my previously expressed conviction that where actual injury to the navigation had been produced, it was only of a temporary character, and would disappear as the principles of the design were carried out The accumulation of sand in the harbour channel I believed to be due in great measure to exceptional causes, though I was not prepared to explain the whole action I thought however, that certain obvious evils were caused by the position of the end of the groyne, and recommended its immediate extension for 1,500 feet, also that some assistance should be given to the natural scour for the removal of the opposite shore of Deep Water Point, so as to bring the force of the current nearer to the Manora shore.

With respect to the monsoon action on the bar, I cited it as a confirmation of the opinion originally expressed by Mr. Walker and myself, that the south-west seas were an active agent in its formation and maintenance, and that it must be shelted from them before any material measure of improvement of the entrance could be looked for I therefore recommended the immediate construction of the Manora breakwater as laid down by Mr. Walker, but without pledging myself to its sufficiency.

On receipt of this report, the Bombay Government immediately sanctioned the extension of the groyne and the removal of hard mate-

rial from Deep Water Point, which works were duly completed in the course of the following year (1865).

The construction of the breakwater (of which the estimated cost was about £1,20,000) was recommended to the Secretary of State for his sanction.

In the meantime, Colonel Tremenheere, with my report before him, prepared an elaborate statement of his views, which he embodied in a report to the Commissioner of Sind, dated 19th May 1864.

In it he gives the following summary of his opinions —

1st. The peculiar position of the harbour with reference to the monsoon surf acting on the shallow coast has not hitherto met with sufficient consideration.

2nd. The increased velocity given to the tides by the construction of the groyne, has increased the size and height of the bar, instead of opening a passage through it, or scouring it into deeper water, as was intended.

3rd. The tidal water to fill the harbour being now drawn from the vicinity of the breakers on the bar, and carried at a high velocity through a narrow deep funnel, is much more laden with sand, silt, and mud than it was formerly, and the amount of such sedimentary matter brought in by the flood during the monsoon, much exceeds what can be lifted and carried out by the ebb tides, so that the amount of deposit within the harbour must annually increase.

4th The result of extending the groyne still further must be to draw water during the flood tide still more heavily charged with sand, and to cause still more rapid injury to the harbour.

5th The bar has increased both in length and width and height since the works were commenced, and the depth of water in the entrance channels has been materially reduced

6th. We find, both within and outside the harbour, the preservation of the general form, combined with a change of material from very light to heavy sand, a result which it should be an engineer's object to avoid.

7th. The proposed breakwater would not afford any effectual shelter to that part of the bar which Mr. Parkes wishes to scour away, and it is very improbable that a deep channel could be formed in that direction.

It may be at once stated that the *2nd*, *3rd*, *4th*, *5th*, and *6th* of these conclusions have been brought to the test of experience, and not one of them has been confirmed They are based entirely on the observation of effects which have since disappeared, and the only yet remaining injurious effect of the works in their incomplete state is the lengthening of the bar to the eastward. Though longer, however, the bar is both narrower and lower than formerly, and the channel round its end is as deep and twice as wide as it was originally. With respect to the *interior* of the harbour the improvement is indisputable. These five objections therefore may be considered as removed from the pale of discussion.

The first objection is supported by a theory for the first time promulgated in this report, and as to which Colonel Tremenheere was silent in his previous communications with me, viz, that there is during the monsoons (when direct observations are impracticable) a coast current produced by the action of the waves running from the mouth of the Indus towards Kurrachee The theory is supported by the fact (disputed by some persons, though I believe admitted by the majority) of the existence of minerals, especially mica, peculiar to the valley of the Indus, in the mud of Kurrachee Harbour, and still more directly by the results of an experiment made by Colonel Tremenheere during the monsoon of 1865, in which, out of a number of bottles set afloat at the mouth of the Indus, a considerable proportion were found on the beach a few miles to the eastward of Kurrachee Harbour. Colonel Tremenheere attributes the existence of the current to the supposed oblique action of the surf on the sandy coast, but in this part of his argument he is believed to stand absolutely alone in the support of some of the more important of his alleged facts and his inferences

This coast current theory has been made the subject of a great deal of discussion, and has been contested from many points of view, but so far as it regards the design for the harbour improvements, the discussion may be concentrated in two simple questions

1st If such a current exists, where is the evidence of its deteriorating effects upon a harbour of such acknowledged vitality as Kurrachee?

2nd. Even if it be calculated to injure the harbour, what can better mitigate the evil than the Keamaree Groyne, which provides, in the angle between it and Keamaree Island, a trap for all silt brought from the eastward, from whatever scource, and prevents its entering the harbour?

After the lapse of four years, no facts or arguments have been brought forward which suggest replies to either of these questions

With reference to Colonel Tremenheere's seventh conclusion, it appears to have been based on an imperfect conception of the objects which it was hoped would be effected by the breakwater, and upon a theory as to the improbability of the scour taking a certain direction, of which it may now be confidently said that it has been disproved by experience.

These points are more fully discussed in my report of the 10th August 1868.

Colonel Tremenheere concludes by a recommendation that the whole question should be referred for the opinion of scientific men.

This report, as above stated, was dated May 1864. In September 1865, sixteen months later, the Government of India recommended that the questions at issue between Colonel Tremenheere and myself should be referred to some independent engineer for his opinion, and in accordance with this recommendation, Messrs. D. and T. Stevenson, of Edinburgh, were instructed by the Secretary of State to report on the following questions.—

1st. The validity or otherwise of Colonel Tremenheere's objections and the consequent expediency or otherwise of stopping the works

2nd. The amount of probability on general considerations, that Mr. Walker's plans, if prosecuted to completion, will effect an improvement of the harbour commensurate with their cost.

Messrs. Stevenson's report was presented on the 26th February 1866. Although the form of their conclusion is favorable to Colonel Tremenheere's objections, yet their line of argument shows no one point of contact with Colonel Tremenheere's. Of the various questions at issue between him and myself, many are not mentioned, a decision is not even pretended to be given upon any one. They state that they hold one opinion even more strongly than Colonel Tremenheere and myself, though there is nothing in Colonel Tremenheere's report to show that he holds it at all, viz, the necessity of protection from the sea; and upon the alleged ground that Mr. Walker's breakwater is insufficient for this purpose, they conclude that "Colonel Tremenheere's fears as to the success of Mr Walker's plans are well founded." It will be observed that the sufficiency of Mr. Walker's break-

water was an open question with me in 1864, and Messrs. Stevenson lay down no principle for the determination of what the extent should be. They do, indeed, say that the whole of the extensive sandbank called the Bar must be thrown completely under shelter, but this is a condition which may be interpreted with great latitude, and in a very reasonable sense may be met even by Mr Walker's short breakwater

On the whole, it may be said that Messrs Stevenson's report served to obstruct the progress of the works as designed by Mr. Walker, but did not give the slightest clue to the principles on which an improved design might be based.

Messrs Stevenson's report was made the ground of an order by the Secretary of State, issued in April 1866, to "stop the works." There were no works at that time in progress, all those already sanctioned having been completed, but the order, of course, involved the refusal to the sanction of any new works.

The Government of India acquiesced in this decision, considering that, though the improvement of Kurrachee Harbour was an object of great importance, it would be better to wait till some plan commanding general confidence should be proposed.

The Government of Bombay pointed out the inconsistent character of Messrs. Stevenson's conclusions, and suggested a further reference to them for explanations, to be followed, in the event of this second reference not resulting in a withdrawal of their unfavourable decision, by a still further reference to some engineer whose authority would justify the summary condemnation of Mr. Walker's designs.

Lord Cranborne, then Secretary of State, did not adopt this suggestion, but in January 1867, he practically admitted an appeal from the previous decision by referring the question to Sir Seymour Fitzgerald, then just appointed to the Government of Bombay.

Owing first to the monsoon, and then to the pressure of business connected with the Abyssinian expedition, His Excellency was unable to visit Kurrachee till January 1868. In that month, however, he did so, accompanied by General Tremenheere, and after a full investigation of the whole matter and of General Tremenheere's objections, he transmitted to Sir Stafford Northcote a strong recommendation for the immediate resumption of the works as designed by Mr. Walker

In the following June, under instructions from the Secretary of

State, I proceeded to India, and after full reconsideration of the whole subject in conjunction with the local authorities and officers, I reported my conclusion as to the effects of the works already executed and my recommendations as to future proceedings

My conclusions may be summed up as follows —

That the works already executed had a very beneficial effect on the interior of the harbour, expelling from it about two and a quarter millions of cubic yards of sand, by which the water space of the anchorage was increased 14 per cent., while, by rendering the courses of the tidal currents more regular, they had made it so much more secure that the number of ships capable of being moored was increased from 20 to 55, and those of a larger tonnage.

That the injurious effects produced upon the bar and entrance immediately after the completion of the groyne had disappeared, leaving the navigation practically what it was before the works were commenced.

That, although no actual improvement of the entrance had been effected, certain conditions necessary for effecting improvements had been established, which would produce useful results when supplemented by other conditions not yet provided.

Upon these conclusions I based the following recommendations.—

That the breakwater, nearly as originally laid down by Mr. Walker, should be constructed, and, with a view to directing the scour of the ebb tide into the most advantageous lines, the bar and some of the shoals in the lower part of the harbour should be dredged:

That the obstructions in the entrance, originally caused by the too sudden addition of scour to the harbour having been now cleared away, there was no further necessity for delaying the admission of the Chinna Creek waters into the harbour, the scour of which would effect a great improvement in the channel up to the wharfs near the town.

That, in order to ensure unity of purpose in the further prosecution of the works, the general direction of them should be placed in my hands as consulting engineer, in direct communication with the officers of the Public Works Department now in charge of the works.

These recommendations, having been duly considered by the Secretary of State and by the Governments of India and of Bombay, they were sanctioned by the former in the month of November last.

W. P

No. CCXLIV

ON WAVES OF WATER.

To the Editor of the Roorkee Professional Papers.

DEAR MR. EDITOR,

Though many people now understand what is meant by a *wave*, and know that it is not the motion bodily of the fluid in which it occurs, but is the transmission from place to place of a local state or condition of the fluid, yet I have not met with one person in this country who understands, what I may term, the *mechanism* of a wave of water. The subject is very curious and instructive I think, therefore, you will not object to allow me a brief space in your Journal to make some remarks by way of practical deduction from the mathematical theory of waves of water.

It is often said that theory and practice are at variance with each other This I deny It is a libel upon theory—by which I do not mean hypothesis, but the deductions of reasoning by the use of mathematical symbols and processes The practical man proposes a problem for solution accompanied by a heap of data, which his ignorance of mathematics prevents his seeing to be quite unmanageable. The physicist, or theoretical man, sees at a glance that this is the case, he selects from them a few of the simpler data, and upon those selected data completely solves the problem. He does not profess to have solved the practical man's problem. And therefore to say that theory and practice differ, is absurd The solution, *on the premise assumed* is absolutely true and were the practical man to make the experiment with those selected data, he would find it to be the case The solution of the problem originally proposed would have been best; but it was impracticable. Never-

theless the solution of the more limited problem is highly useful. It points out the kind of phenomena which are to be looked for in the actual cases of nature, and it enables the observer to assign the phenomena actually seen to the right *kind of cause.*

What I am going now to undertake will illustrate this. The variations in the width, depth and direction of the river Hooghly are such as to baffle every attempt to calculate the motion of the tide mathematically. But we may take a simpler case and learn much from it.

The case I will take is that of a straight Canal of uniform depth and width joining two seas, and waves passing steadily from one to the other through the canal, without any disturbing cause such as wind, occurring.

The great authority in the mathematical theory of waves is Mr. Airy, the Astronomer Royal, who, some years ago, wrote an elaborate and very able article (of 150 quarto pages in small type) on "Tides and Waves," in the *Encyclopædia Metropolitana.* Among other problems he took the example I have enunciated above, and the two laws of equable fluid pressure and of fluid continuity led him to this result: If x and y are horizontal and vertical co-ordinates to any particle of the water when at rest, measured along the bottom and from the bottom of the canal, X and Y the displacements of that particle from its place of rest at the time t, owing to the wave motion, λ the length of the wave, k the depth of the water in the canal when at rest, then

$$X = A\left(e^{\frac{2\pi y}{\lambda}} + e^{-\frac{2\pi y}{\lambda}}\right)\cos\,(nt - mx + B)$$

$$Y = -A\left(e^{\frac{2\pi y}{\lambda}} - e^{-\frac{2\pi y}{\lambda}}\right)\sin\,(nt - mx + B)$$

where A and B are constants independent of x and y, and m and n are connected by the condition

$$n^2 = mg\,\frac{e^{2mk} - 1}{e^{2mk} + 1}$$

The forms of X and Y show, at a glance, that the particle will move in an ellipse with its major axis horizontal, and the ratio of the semi-axes—

$$= \left(e^{\frac{2\pi y}{\lambda}} + e^{-\frac{2\pi y}{\lambda}}\right) \div \left(e^{\frac{2\pi y}{\lambda}} - e^{-\frac{2\pi y}{\lambda}}\right) = \frac{e^{\frac{4\pi y}{\lambda}} + 1}{e^{\frac{4\pi y}{\lambda}} - 1}$$

The smaller y is, that is, the nearer the particle is to the bottom of the canal, the larger is this ratio, that is, the *flatter* is, the ellipse, and when $y = o$ at the bottom of the canal, it becomes a straight line, and its length is $2 A$ in ascending from the bottom of the canal, the ellipses in which the particles revolve become longer and longer, and less flat.

If λ the length of the wave is very great compared with the depth of the canal, which is the case with the tidal wave which I am considering, we may expand the exponentials and neglect very small quantities.

In this case—

$$X = 2 A \cos (nt - mx + B), Y = -\frac{4 \pi A}{\lambda} y \sin (nt - mx + B)$$

Suppose h is the height of the wave's crest above the line A E, then

$$\frac{4 \pi A}{\lambda} k = h, \text{ and } \therefore 2 A = \frac{\lambda}{2 \pi} \frac{h}{k}$$

and $X = \frac{\lambda}{2 \pi} \frac{h}{k} \cos (nt - mx + B), Y = -y \frac{h}{k} \sin (nt - mx + B)$

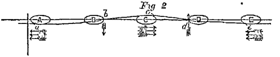
and the ellipses will be all very flat, and of the same horizontal length.

I will now, from what has gone before, construct the wave or show its mechanism.

Let the straight line AE in *Fig* 1, represent the surface of the water when it is at rest and let AE equal the length of a whole wave including both the crest and the trough. Divide it at B, C, D, into four equal parts and draw the five ellipses which represent the complete excursions of the particles of water, at those points where there is motion, now under the action of the waves passing from left to right.

Fig 1

Fig 2



(There is no attempt to draw the figures in any proportion) In these ellipses, the position of the particle in each will evidently be one quarter of a revolution behind the particle in the previous one for, by the time each particle has completed one revolution, the surface will be in precisely the same state that it was in, when that revolution began,

that is, one complete wave must have passed by, and as it moves uniformly, must have passed the points in succession at intervals of one quarter of the time of transmission of the wave, or of one revolution of the particles. Supposing that, at any instant, a is the position of the first particle, then necessarily at that instant b, c, d, e (as shown in figure 1) are the places of the other particles and intermediate particles along the surface would have intermediate places, and the curved line $a\ b\ c\ d\ e$ would pass through all the particles of the surface, and define at that instant the form of the wave.

It will be observed, then, that the height to which the wave rises above the level, and the depth to which it sinks below the level, equals the greatest vertical excursion of the particle. But the length of the wave may be very much greater than the greatest horizontal excursion of each particle hence also, the velocity of the wave may be much greater than the velocity of the surface of the water, for while the wave moves over its length from a to e the surface of the water has moved to the right and to the left, in each case, only over the length of the ellipse. This clearly represents to the mind how a current is made by the tide which will move boats along, but that the current is much slower than the tide itself

Below A, the ellipses, in which the particles beneath the surface are moving, are flatter the lower we go, but are of the same length, and at the instant represented in *Fig* 1, the particles in the vertical beneath a are all moving downwards (with a slower and slower motion) somewhat towards the left In the same way, the particles below b are at this instant moving horizontally and towards the right The effect of this, viz, the efflux of particles past the verticals both at a and b from the space between them, is to lower the wave between a and b and bring it, after one quarter of a complete tide, into the position shown in *Fig*. 2. So between the verticals at b and c, the influx below b during one quarter of a whole tide, equals the efflux below c in the same time hence the amount of water above the level is the same at the end as at the beginning, but it has a reversed form, as shown in *Fig*. 2.

Similar remarks may be made regarding the other half of the wave from c to e, the trough

These results are very curious. and show the powerful assistance which mathematical analysis gives in unravelling the complicated action

of fluid pressure. It is not difficult to see how an elevation of water would press down through the fluid and, sinking itself in the effort raise the level of the water in advance of it, and so cause a wave, but it is beyond our ordinary powers of observation and modes of thinking to conceive how the water moves internally in itself in the process. and it is not in the least obvious why the pressure, by acting backwards as well as forwards, should not produce a wave in each direction. But the mechanism which mathematical analysis enables us to detect, explains these matters completely

There are one or two additional remarks which I will make, gathered from the diagram, (1), It will be seen that the crest of the wave *ac* is shorter than the trough *ce*, by twice the total horizontal motion of each particle, and that therefore low water in such a canal lasts longer than high water This is frequently noticed, (2), The tidal current is quickest at high and low water, and (3) the tidal current is running in the same direction for equal times *before* and *after* high-water; for *all* the particles between *a* and *c* are moving towards the right hand, and for places between *c* and *b* the tide is rising, and for places between *b* and *a* the tide is falling. The same may be shown of low water.

The practical man would immediately say, "Here is an instance of theory and practice being at variance, for it is notorious that high-tide and turn of tide-current occur about the same time." This is no doubt generally the case up rivers, but on coasts and at the mouths of rivers, there is generally a long interval, approaching to three hours, between the turn of tide and of the tide-current, which fact, the above theory most clearly explains

You have not space, and I have not time, to give an account of the various practical problems which Mr Airy has solved, and by which we see, from the side of theory, what is to be expected when various obstacles are presented by nature. He finds the separate general effect on the wave, of a gradual shelving of the bottom of the canal, of a gradual contraction of the channel, of friction, of a barrier thrown across the canal at some distance. and he finds remarkable illustrations of his theoretical results in various localities For instance it is notorious that there is no sensible tide in the Mediterranean except at Gibraltar *and* at Venice! The appearance of this latter is a singular confirmation of the effect of a barrier, which in

this case is the head of the Gulf of Venice And, indeed, theory is remarkably born out in the combined effect of all the causes of departure from the normal type of the canal which I have just enumerated. For Mr. Airy shows that the tendency of all of them in a river-tide is to diminish the interval between high-tide and turn of tide-current, and therefore the practical man, whose exclamation I have just quoted, must change his note.

How our poor ellipses get contorted into other shapes by the action of the fluid pressure, which with such precision communicates to the particles the effect of every push which banks and sands and winds impart, it is impossible to say. But nevertheless, I think, that the accurate knowledge of what does take place, when these external disturbers of the ellipses' elegant forms are not allowed to intrude, is both curious and also highly instructive for enabling us to comprehend the *kind of action* which takes place, even in the more complicated combinations which nature generally presents.

Yours faithfully,

J. H. P.

CALCUTTA,
June 28th 1869.

No. CCXLV.

EMBANKING THE HOOGHLY.

Note by LIEUT.-COLONEL F. H. RUNDALL, R.E., *Chief Engineer to the Government of Bengal, Irrigation Department, on the protective works constructed on either bank of the river at the mouth of the Hooghly.*— Dated 26th February 1868.

In January 1865, the Government of India called for a report on "the exact nature of the protection hitherto given to the country at the mouth of the Hooghly on both banks from inundation from the river or the sea," and as to "the feasibility of affording complete protection to that region against irruptions of cyclone-waves* by a sea-dyke like that constructed in the Hidgellee District."

The then Chief Engineer, Colonel Beadle at once drafted a memorandum explaining generally the nature of the works existing on the Hooghly and its feeders within tidal influence, and the degree of protection afforded to the districts of North and South Hidgellee, Tumlook, and the 24-Pergunnahs.

He then explained that the districts on the left bank of the Hooghly had never been considered to be protected against a cyclone-wave, but rather against extraordinary tides and ordinary storms. On the Hooghly face, the embankments were of considerable section, and might have proved a protection against an ordinary cyclone; but for the remainder

* The losses, caused by the storm-wave during the cyclone of 1864, which inundated an area of 1,500 square miles, amounted as follows —

Human beings,	No	17,800
Cattle,	,,	136,000
Shipping property,	Rs	1,00,00,000
Government standing property,	,,	8 50,000
Private standing property,	Beyond computation	

of the enclosure on the Soonderbun side and back to Tolly's Nullah, the embankments are simply sufficient for the exclusion of the spring tides.

He added his opinion that nothing more should be attempted, but that "the work of Government should be confined, as much as possible, to maintaining the exact cordon of embankment shown in the Revenue Survey Maps, and that they should be nowhere higher than 5, and less than 3, feet above spring tide"

He at the same time stated that it would be quite as feasible to construct a dyke along the river's margin from Channel Creek to Hooghly Point as it had been in Hidgellee, and so far complete protection to be given to, not only the more exposed side, but to the Soonderbuns also. It was equally possible to protect the country lying between the Rivers Russulpoor, Huldee, and Roopnarain in a similar manner As, however, it was impossible to tell on which point a cyclone-wave might be precipitated, it became necessary, in order to ensure *complete* protection, to give it at *every point.*

Colonel Beadle, however, argued that it was not only a matter of expense, but of other considerations, whether the volume of water so forced up the Hooghly should not be allowed to expand, and considered that the wide open mouth of the Roopnarain proved the safety of Calcutta itself on these occasions He therefore deprecated the experiment of such complete embanking against a cyclone-wave being carried out

Lieutenant-Colonel Short, the Superintending Engineer who had been connected for years with the embanked tidal districts on the right bank of the Hooghly, some months afterwards, submitted a series of reports, evidencing much care, time and labor in their preparation. These treat the subject exhaustively as far as regards the protection hitherto afforded, and the extent of work that would be necessary to provide complete protection against similar calamities. I apprehend, however, that the Government of India required from this Government not so much a series of definite proposals, as a general expression of opinion on the feasibility of affording complete protection, including therein its practicability not only from an engineering, but also from a financial, point of view. Of the former, Colonel Beadle expressed himself satisfied, a judgment could be arrived at on the latter, only

after the extent and nature of the work required had been determined

For this purpose it will be necessary to consider briefly the following points —

I.—The districts exposed to the action of the cyclone-wave on either bank of the Hooghly;

II —The effect of that wave,

III —The extent of protection at present afforded, its adequacy or otherwise to resist such a wave;

IV —The further measures needed to afford complete protection;

V.—Their cost,

VI.—The means at the disposal of the Government for meeting the expense.

VII.—The effect of the proposed protection, if completely carried out, on the reclamation of land and the revenue derivable therefrom.

VIII —The possible effect on Calcutta itself, if the exposed country were to be protected by a dyke completed all the way on both banks from the sea.

I.—The districts exposed to the action of the cyclone-wave reckoning from seaward on the right bank are.—

South Hidgellee,	Mysadul,
North "	Tumlook,
Doro Dummun,	Lower and Upper Mundulghât.

and on the left bank—

Saugor Island,
Soonderbuns, and
24-Pergunnahs.

It is not necessary here to enter into a description of these districts and their boundaries, it will be sufficient to remark that they are all similar in character, soil and produce, well cultivated, but lying on so low a level as to require embankments for protection, from even the spring tides, by which they would otherwise be submerged.

The gross area of the districts lying on the right bank of the Hooghly may be stated in round numbers, at 758,500 acres, yielding to Government a revenue of Rs. 8,75,300, inclusive of about 110,000 acres

which have hitherto been given over for fuel and the manufacture of salt.

II —The effect of the wave, though very disastrous on all these districts, was greater in some than in others. As regards South Hidgellee, wherein the sea-dyke which was then in course of formation had been completed, it proved, even in places where the turf covering was wanting, a sufficient protection, notwithstanding that the wave rolled along it to a height of 11 feet 4 inches, or to within four feet of the crest. The injury that the district sustained was wholly owing to the wave rolling up the unprotected drainage channels, three of which—the Ramnugger, Mirzapoor, and Peechabunnee—having large open mouths, felt the full force of the wave, which of course found its way into the country at the back of the dyke, and so swept everything before it.

The height of the storm-wave on the dyke, over a length of 23 miles 2 furlongs, appears to have been greatest at the Russulpoor, decreasing in level gradually along the coast line westwards, until at 12 miles distance, or at the Peechabunnee Khal, it was barely above spring-tide level.

In North Hidgellee, at Kowkally Lighthouse, the storm-wave is found to have reached its highest level, or $16\frac{1}{2}$ feet above high spring tides, or nearly five feet higher than it was at the Russulpoor. At Kedgeree, three miles higher up, the wave was one foot less, and at a place eight miles further still, it was one foot less than at Kedgeree. As all along this portion, the embankment was only 10 feet in height, it was overtopped throughout and breached in numerous places.

In the adjacent Pergunnah, Doro Dummum, which is the most exposed to the action of a cyclone-wave, being a low tongue of land projecting far out into the Hooghly, the greatest injury and consequent excessive loss of life arose, more from the numerous open khals up which the wave rushed, than even from the breaches in the embankments which encircle the Pergunnah The actual height of the storm-wave was found to have been 13 to $13\frac{3}{4}$ feet above mean sea-level, but 4.4 feet lower than the level reached at Kowkally, and three feet below that at Kedgeree. The embankment along the south-eastern face was nearly all swept away, but that along the north-east was not so much injured

In Pergunnah Mysadul, at the southern boundary, which is six miles

up the Huldee, the wave was only 10 feet above the level of the land outside the embankment, and decreased in height as it travelled up the Huldee or Cossye, until, at a point $19\frac{1}{2}$ miles up that river, it was finally lost. Along the northern boundary which borders the Hooghly, the wave was $12\frac{1}{2}$ feet above the land level, and overtopped the embankment 1 to 2 feet, while, as in other cases, large volumes of water forced up the open khals, caused probably more injury than that which entered by the breaches in the embankment

In the District of Tumlook, the greatest injury was experienced on the right bank of the Roopnarain, between the Banka and Narainpore Khals, the wave rising to 12 feet above the level of the land, or $4\frac{1}{2}$ feet above the crest of the embankment This portion of the river was exposed to the direct action of the wave, and consequently the injury done there was greatest, the town of Tumlook itself being nearly levelled with the ground.

In Upper Mundelghât, at its southern extremity, the wave rose about 10 feet above the land level At Koilahghât, on the Midnapore Road, it rose $6\frac{1}{2}$ to $7\frac{1}{2}$ feet, and apparently expended itself by the time it had reached a point six miles above Koilah.

Lower Mundelghât, or the strip of land contained between the Hooghly, Damoodah and Roopnarain, was inundated to a depth of 14 feet, the wave having risen that height above the level of the country at the mouth of the Damoodah, gradually decreasing till at Oolabarria it was only about 7 feet. The embankment, which was only $6\frac{1}{2}$ feet high, was breached of course in many places, but not so utterly destroyed as might have been anticipated, but the volume of water entering by all the open khals, as in every other instance, caused great destruction

Such briefly was the effect of the storm-wave on the several districts situated on the right bank of the Hooghly. On the left bank, it may be shortly stated that the part which suffered most was the north of Saugor Island, inasmuch as it was exposed to the wave which rolled up on either side by the Hooghly and by Channel Creek. Its height here was under 13 feet above the level of the land The portion of the Soonderbuns which suffered was in a circuit 10 miles north and east of Saugor Island. As the wave spread to the interior of the 24-Pergunnahs eastward of that limit, its height, and consequently the dam-

age it occasioned, was less The tract which however suffered most severely was the Diamond Harbour Sub-Division, as the embankments there were but 9 feet high, while above Silver Tree Obelisk to Hooghly Point they were completely swept away.

III.—The protection hitherto afforded to all of the above-mentioned districts has, with the exception of South Hidgellee, been confined to excluding an ordinary storm-wave. In South Hidgellee, as has been stated, the sea-dyke had been commenced, and as far as it was completed, proved quite a sufficient protection even against such an extraordinary visitation as that in October 1864. Above Diamond Harbour, on both banks of the river, however, the embankments have been confined to affording protection only against extraordinary spring-tides, and are therefore inadequate to keep out an ordinary storm-wave, much less that arising from a cyclone

IV.—As regards the further measures needed to afford a complete protection, several recommendations are made in Colonel Short's Reports, the principal one being that, from the experience of the cyclone of 1864, it may fairly be concluded that a sea-dyke of such height, as observation at the several places along the Hooghly and its tributaries has shown would have been sufficient for the protection of the country, may safely be constructed, provided that at the same time measures are taken for closing either with dams or sluices the numerous khals which are at present left open Colonel Short advocates a re-alignment in many places, and shows that, proper judgment being exercised, a large area of land hitherto given up to the manufacture of salt may be reclaimed and made to yield a considerable revenue by way of return for the outlay.

V.—The highest embankment which Colonel Short has shown would be necessary, is under 20 feet at the mouth of the Huldeo, and the lowest 14 feet in Upper Mundelghât, decreasing to the height of the present embankments, or 6 feet above Koilah. A bank 20 feet high, with slopes of 3 and 2 to 1, would contain 1,120 square feet, and one of 14 feet about half that quantity. The former in round numbers would cost about Rs 16,000, and the latter Rs. 8,000 per mile.

The length of dyke that would be required, supposing that the open khals were secured by sluices, would probably be about 320 miles. The length requiring the larger section would be only that between

the mouth of the Huldee and Roopnarain on the right bank, and between Hooghly Point and Channel Creek on the other, so that an approximate cost of the dykes, exclusive of sluices, would be—

Rs		Rs
80 miles at 16,000		12,80,000
140 „ 8,000		11,20,000
100 „ 5,000		5,00,000
	Total,	29,00,000

The sluices would probably cost eight to ten lakhs more, or including contingencies, the whole could possibly be done for 40 lakhs

VI —The sixth point, *viz*, the means at the disposal of Government for executing this work, if thought advisable, must now be considered

The funds provided for embankments in the above districts consist of a special cess of $1\frac{1}{4}$ anna per beegah set aside at the date of the permanent settlement, and Colonel Short has shown that there is an annual sum of Rs 85,090 available for the maintenance of embankments within tidal limits This sum has been received annually since 1798, so that up to the year 1865, or in a period of 66 years, it has amounted to upwards of a total of Rs 56 lakhs The expenditure during that period is not so readily obtainable. Colonel Short estimated that up to 1860, about 12 lakhs might have been laid out in the Districts of Hidgellee, since that time Rs 19,54,800 more have been expended The total outlay on embankments within tidal influence during the last 10 years has been Rs 23,20,000.

VII —The seventh point, *viz*, the effect that the proposed protection, if completely carried out, would have in the reclamation of land and in an increase of land revenue, will best be considered along with the question of cost

Colonel Short states that, out of 29 Pergunnahs in Hidgellee, only nine have been permanently settled, while the remaining 20 are to be re-settled in 1868, or the present year. He estimates that this re-settlement should, if the Pergunnahs be thoroughly protected, yield Rs 1,15,000 yearly. In addition to this, about 1,10,000 acres would be reclaimed and, when also similarly thoroughly protected, could easily bear an assessment of 12 annas per beegah, or Rs 2-4 per acre, so yielding a revenue of Rs 2,47,500 These two sums would aggregate Rs. 3,62,500, or about 9 per cent on the above estimated outlay of

40 lakhs. To this sum of 40 lakhs, however, must be added the sums recently expended on the sea-dykes and other detached bunds, so that probably, under the head of complete protection, not less than 50 lakhs must be considered as the probable aggregate outlay To cover interest at 5, and repairs at $2\frac{1}{2}$, per cent, which is a liberal allowance, $7\frac{1}{2}$ per cent on 50 lakhs or Rs 3,75,000 would be required, so that the above-mentioned sum of Rs 3,62,000 would be nearly sufficient for the purpose. There is, however, the annual amount of Rs 85,090 already levied, and to which must be added Rs 16,786, the allowance for the 24-Pergunnahs, making a total of Rs. 1,01,876 besides, to meet the cost of repairs, which however would probably not exceed $2\frac{1}{2}$ per cent on the capital outlay, or about Rs. 1,25,000.

It is not, however, merely to the direct increase of revenue that the Government has to look as remuneration for such an expenditure, but in saving, for the future, such losses as they have heitherto experienced, directly, by large remissions of revenue, and indirectly, by the diminution of the population and impoverishment of the survivors of such a calamity. The legal obligation under the terms of the settlement extends no further than the provision of protection from the tides It is also certain that, with all the other innumerable claims upon their resources, the Government cannot undertake extraordinary works of a gigantic character, unless the people profiting thereby are prepared to contribute a return for the outlay, which is to secure them, not only their property, but their very lives. But if, as would appear from the reports before the Government, such return may be secured by the re-settlement of those Pergunnahs which from their hitherto exposed condition have been assessed at a very low rate, as also by a judicious reclamation of land at present yielding no revenue at all, it becomes a question worthy of serious consideration whether it will not be desirable on every ground to carry out these protective works on such a scale as will prevent the recurrence of such wide-spread disaster, and therefore I hesitate to endorse the opinion of the late Chief Engineer, Colonel Beadle, as given in the memorandum quoted at the beginning af this Note

VIII.—There is, however, one more most important point for consideration, and that is, the possible effect that might be produced on Calcutta itself if the present exposed country were to be completely

protected This is a point on which I feel diffident in expressing an opinion, as I am but imperfectly acquainted with the action of a cyclone-wave.

I am, however, disposed to think that the contraction of the waterway or rather the confinement of the wave between the banks of the river, would not tend to increase the distance up which the wave would travel, or the height to which it would be raised. Judging from the effects of previously recorded storms, the height of wave appears to be proportional to the force of the wind. I therefore by no means feel sure that it is an additional quantity of water that is forced into the channel of the river, so much as the unnatural raising of the surface at the points over which the cyclone itself passes. The height of this wave is also in a measure dependent on the depth of the water at those points Every one knows that waves generated on *shallow* reservoirs are much lower than on those which are *deep* Also, that the water is piled up by the wind on the lee-shore or bank to a higher level than it is to windward. Now this action is independent of the area of the reservoir, and is generated without any addition of volume, and solely with whatever quantity of water there happens to be in it at the time. Similarly I infer that the water on the river acted upon by the wind is raised above its ordinary level in calm, just in proportion to the force of wind passing over it, and is precipitated forward until it meets with an obstacle That obstacle does not necessarily *further* raise the *level* of the water as it would do in the case of a storm-flood draining off a country by means of a river into the sea. In that instance, there is a continual accession of volume pouring down *from a higher level*, which will in time overtop any opposing obstacle, and continue to do so until the whole quantity has run off In the case of the cyclone, I believe the wave would be as great, if not greater, at the ebb than at the flood-tide, as happens ordinarily when the southerly winds are blowing strongly up the Hooghly Of course, if the cyclone occurs at flood-tide, there will be the accession of whatever quantity is due to the rise of tide, but the highest tides often occur without the presence of any wind at all During the southerly winds, I believe, the level of the sea in the whole of the upper part of the Bay of Bengal is permanently on a higher level. But I do not think a cyclone would raise the level of the Bay itself, however high it might raise the *wave* immediately in

its path, and it must be borne in mind that the level of the Bay at the time of the cyclone of October 1864 must have been low, as the south-west monsoon had ceased blowing for some weeks

In the cyclone of last November, no additional quantity of water appears to have entered the Hooghly, or the tide to have been more than ordinarily high, and yet to the eastward of Calcutta the cyclone passed over the Bay, and if it had any effect in raising the level of the Bay *more than locally*, the result *must* have been felt in the Hooghly

I therefore draw the conclusion that the elevation of that wave does not necessarily imply a corresponding accession of volume, which, if opposed, as in the case of a descending rainflood, must necessarily be raised higher by the obstacle it meets, or because its path is confined

Hence I have no apprehension that any greater effect would be felt at Calcutta after the complete embanking of the Hooghly against a cyclone-wave than was felt before in 1864

As said before, I put forth these opinions diffidently, merely as the result of my own reflections on the subject and not with any preten-sion to their being correct conclusions or explanations of the action of a cyclone-wave

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From Colonel C. H. DICKENS, R A, *Secretary to the Government of India, P W Department, to the Joint Secretary to the Government of Bengal P. W. D*,—No. 68 I, dated 25th April 1868.

I am directed to acknowledge receipt of your letter., dated 20th February last, on the subject of the feasibility of affording protection to the country at the mouth of the River Hooghly from irruptions of cyclone-waves

This question is without doubt one of very great importance to the people of Lower Bengal, and it is therefore desirable that no time should be lost in endeavouring to arrive at a conclusion as to the expediency of attempting to embank out the extraordinary waves caus-ed by the violent storms with which that region is liable to be visited.

The Lieutenant-Governor is of opinion that the matter should be considered by a Committee of Engineer and other scientific Officers, and to this course the Governor General in Council has no objection, and such a Committee may at once be appointed, if, on reconsideration, His

Honor does not consider that it would be preferable to entrust the enquiry to Mr. Leonard or some other single selected officer

It will be desirable that the Committee, or officer selected, should obtain the best possible statement of the facts with reference to the precise manner in which the water rose and fell on the occasion of the cyclone of 1864, and the times of rise and fall in relation to the passage of the cyclone at the various parts of the Hooghly from the Sea to Calcutta It may be possible, by careful investigation, to arrive at some facts which will throw light on the critical point at issue, which is, whether by preventing the spread of the water at the mouth of the river, the rise is likely to be aggravated higher up. The consideration of what occurred at several parts of the channel where sudden contractions of capacity or sudden expansions take place, may, by the light of actual observation of facts, help to arrive at a conclusion on this important point. His Excellency in Council, as at present informed, is disposed to the opinion that the raising of embankments would not be attended with danger That some exaggeration of the rise of the storm-wave may take place in a funnel-shaped opening is not unlikely, but with so long and so winding a river as the Hooghly, it seems probable that no general accumulating tendency to raise the height of the water would be developed, and that this action would end near the place where the channel first becomes decidedly narrowed.

A study of the tides would throw light on the question of the increased height of a storm-wave, as the general mechanical laws in both cases would be much alike, and the Secretary of State will be requested to obtain the opinions of the best authorities in England, as to the effect of embankments at the mouth of a river on such a wave as the cyclone produces

But, whilst admitting that the importance of the subject demands that the fullest investigation should be made, the Governor General in Council does not consider it necessary that all practical action should be delayed, pending the result of the enquiry There is, it is thought, a quite sufficient *primâ facie* case to show that effective embankments from Diamond Harbour upwards may be constructed without danger, and with a certainty of being financially reasonable and profitable I am, therefore, to request that detailed projects and estimates for such portion of the work as the Lieutenant-Governor, under Colonel Run-

dall's advice, may deem proper for execution, may be sent up so as to admit of the work being undertaken during the next cold season.

From the Government of India, to the Secretary of State for India,— Dated 25th April 1868

We have the honor to forward the accompanying copy of a correspondence with the Government of Bengal on the important subject of the feasibility of affording protection to the country at the mouth of the River Hooghly from irruptions of cyclone-waves, and for the reasons stated in our Secretary's letter of this date, to request that you will be so good as to consult the best authorities in England as to the effect of embankments at the mouth of a river on such a wave as the cyclone produces. We would suggest Mr Airy, the Astronomer Royal, who is, we believe, the highest authority on the theory of tidal wave motion, and whose opinion, with those of any eminent Civil Engineers whom you may select to consult, would be of much advantage in enabling us to come to a decision on the important point at issue, which is whether, by preventing the spread of water at the mouth of the River Hooghly the rise is likely to be aggravated higher up

The general facts of the cyclone of 1864 can be pretty well gathered from the published report by Colonel Gastrell and Mr. Blandford, a copy of which is enclosed, and will possibly be a sufficient guide to Mr Airy, or any scientific Engineer, in forming a theoretical judgement on the subject

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From G. B AIRY, ESQ , *Astronomer Royal, to the Under Secretary of State for India,*—Dated 6th July 1868.

I have to acknowledge receipt of your letter of June 25th, transmitting to me, by direction of the Right Hon'ble the Secretary of State for India, certain documents relating to the Calcutta cyclone of 1864, October 5th, and requesting my opinion whether, by preventing the spread of water at the mouth of the Hooghly, the rise is likely to be aggravated higher up

I think it possible (without professing myself absolutely certain) that much might depend upon the duration of the storm-wave. Had it been

only one surging swell, I imagine (but always expressing myself with the same caution) that the contraction of the spread in the lower Hooghly would not materially increase the wave in the upper channels. I sought therefore in the "Report" for information on the duration of the wave, but on this special point the information is more meagre than on any other. Still from several Notes, it would appear that the course and duration of the wave, in a great measure, resembled those of an exaggerated ordinary semi-diurnal tidal-wave.

Now the effect of embanking the lower estuary of a river, in modifying the tidal-wave in the upper channels, is, both in theory and in experience, matter of great certainty. In the Thames, we know accurately the depth of the river opposite London when old London bridge was built, proving that the tidal stream must then have been most insignificant, and we know the power of the tidal-stream at the present time and for some time back, evidently produced by the great middle-age embankments (probably about the time of Henry VI) In our own days, and entirely within my recollection, we know how much the Clyde has been modified by the works on it, principally of the character of embanking slobs and marshes

Assuming, then, that the wave in storms of this kind lasts through several hours, remarking also that the proposed embankments would not contract the sea-mouth of the estuary, but would contract the spread of the wave in the lower part and middle part of the estuary, I express, as the best opinion which I am able to form at present, that the construction of such embankments would materially increase the elevation and force of the wave in the upper channels of the river

I am not aware that I can add any collateral remarks of immediate importance to this subject.

From the Government of India to the Secretary of State for India,— Dated 19th September 1868.

In reply to your Despatch, dated 30th July, 1868, with which you forward for our information a letter from the Astronomer Royal, stating his opinions upon the probable effect of embanking at the mouth of the Hooghly on the wave caused by a cyclone, we desire to remark that while we, of course, receive with much respect the conclusion of

so eminent an authority, it would have been more satisfactory if we had been favoured with the grounds of those conclusions in a more explicit form, and if the probable results anticipated by Mr Airy had been stated with greater precision. It will be obvious that the practical question at issue is not whether the embankments, which it has been proposed to form, will cause an exaggeration of the cyclone-wave, but whether that exaggeration will be of such magnitude as to make it impracticable or dangerous to attempt to oppose it

The reports of the actual occurrences show that at the place where the Hooghly estuary first contracts greatly, the cyclone wave rose $16\frac{1}{2}$ feet above an ordinary spring high water, but that beyond that place the wave gradually diminished, and in Calcutta was only a foot or two

Mr. Airy says that the effect of embanking the estuary of a river in modifying the tidal-wave above, is, both in theory and in experience matter of great certainty We infer that it would be within the scope of calculation to estimate approximately the probable result of embankments at the mouth of the Hooghly, both in respect to the tidal-wave and to a cyclone-wave of a quasi tidal character

We should, therefore, wish to be placed in a position to obtain a calculation on the data given by the facts as now ascertained, on the probable effect of such embankments as have been spoken of If Mr Airy could undertake such an investigation himself we should feel under a great obligation to him, and he would be performing a valuable service for the population which now exists at the mouth of the Ganges in perpetual danger of destruction or ruin from the periodical recurrence of cyclones If he should be unable to undertake such a task himself, or to superintend its execution by some properly qualified person, still perhaps he might favor us with his opinion as to the proper manner of setting about the enquiry, and we might then be able to have the investigation and calculation carried out in India

The importance to the entire population of Lower Bengal of a proper knowledge of the extent to which protection can be safely given by means of embankments to the low-lying tracts at the mouths of the Ganges, cannot be overstated, and we feel that our duty requires of us to prosecute the enquiry until some means are found for warding off the danger, or it is proved, in an indisputable manner, that no security can be got. The mere expression of the opinion of the highest authority,

unsupported by the precise grounds on which that opinion is formed, though it may properly cause us to be extremely cautious in the actual prosecution of Engineering works, cannot justify our resting content to do nothing, and to make no further effort to seek a remedy for what, now causes periodical calamites of the most distressing nature.

From SIR G. AIRY, *Astronomer Royal, to the Under Secretary of State for India*,—Dated 27th November, 1868.

I am honored with your Lordship's letter of 13th instant, communicating copy of a letter from the Government of India (Public Works Irrigation), to the Right Hon'ble the Secretary of State for India, dated September 19th, and requesting to be informed whether I could undertake or superintend a calculation on the probable effect of embanking the Hooghly, and whether I could indicate the precise nature of further information desirable for that investigation?

In reply, I can do little more than express my opinion on the extreme difficulty—perhaps the impossibility—of making numerical calculations of the class which enter into this investigation. Even in the places with which we are most familiar, and where the daily recurrence of phenomena is most regular, we cannot sufficiently separate the effects of different causes, to found, on that separation, a numerical calculation. Thus, in the Thames, we know that the funnel form must tend to increase the upper tides, and that friction must tend to diminish them; but we cannot so define the proportions of their effects, as to be able to calculate the increase of tide from the Sea to Greenwich and London, and the decrease from London to Teddington. In the instance of the storm inundation of the Hooghly, our total ignorance of the nature of the external action of the wind on the Sea, and generally of the nature of the ocean-disturbance which reached the Indian shores increases greatly the combination of difficulties

The Secretary for India will remark that, in my letter of July 6th, paragraph 4, although I expressed an opinion distinct in its tendency, I left it entirely vague as to numerical measure. And I must continue to do so. I still am clearly of opinion that, on the recurrence of a similar oceanic swell, the elevation of the water at Calcutta will be

rendered greater by a more perfect embankment of the Lower Hooghly, but I cannot tell how much, and I venture to remark that the occurrences at the late calamitous visitation support the first part of my opinion. Assuming, as a rude representation of the flood in the lower channels, that the ordinary tide was double, I should have expected, that, in accordance with our experience of tides in other rivers, the tide at Calcutta would be doubled, but it was, in fact, very little increased. I attribute this to the extraordinary relief which the flood-current received by its extraordinary opportunity (not given in ordinary tides) of passing over the sea-walls and spreading over the marshes. I think that, if it had been deprived of this relief, it would have passed up the river in great force

For subjects so obscure as this, every mathematician and every engineer, recognizes experience as the best guide. And this remark, taken in conjunction with the idea that I have expressed above, seems to indicate the proper course for further enquiry. There must, I suppose, have been heavy swells from the Sea, not sufficiently high to overtop the marsh embankments, of which some records have been preserved. It is much to be desired that all such records should be collected and carefully considered with special attention to the proportion which they appear to indicate between the rise of the water-surface at Calcutta, and the corresponding rise in the sea-channels. The evidence derived from actual observations of this kind might change my opinion. But failing such evidence, I must refer to my letter of July 6th, paragraph 4, and to the present letter, paragraph 3, as exhibiting the best opinion which the evidence before me warrants me in offering.

In these remarks I will request the Right Hon'ble the Secretary for India to observe that I treat the question as a purely abstract question of hydrodynamics. How much importance is to be given, on the one hand, to the expense of raising the embankments, and how much, on the other hand, to the consideration that the evil resulting from one state of things is certain, while that from the other is problematical, are questions upon which I do not presume to enter

(*To be continued.*)

No. CCXLVI.

MARKUNDA BRIDGE DELHI RAILWAY.

The characteristic features of the Markunda River have already been scribed in Nos. XLV and CXVIII of these Papers

The point at which the Umballa-Scharunpore section of the Delhi ailway crosses it is some miles above the Grand Trunk Road bridge rmerly described. Here the river has a fall of $3\frac{1}{2}$ feet per mile, with wide, sandy bed, perfectly dry in the cold weather, but bringing down large quantity of water in the rains.

The Railway Bridge is of precisely the same kind as those over the umna, Beas and Sutlej rivers on the same line, and which were designed ith a view to the greatest possible economy of construction

The Piers consist of a single well-cylinder of brick masonry, 3 feet ick, $12\frac{1}{2}$ feet in external diameter, resting on a curb formed of wrought-on plates and angle irons rivetted together, and sunk 45 feet through ie sand into the stiff clay below, chiefly by means of the Sand Pump escribed in No. CLIV. of these Papers, and then filled with concrete. welve rods of inch iron, connected at intervals with iron rings, run rough the masonry, being bolted to the curb below, and enabled the ers to be sunk without fear of fracture.

The Superstructure consists of 11 spans, formed of two wrought-iron attice girders (each supporting a line of rails) 110 feet long, the clear terval between the piers being 99 feet One end of each pier is bolted own in the usual manner to a cast-iron bed plate, the other end resting 1 12 cast-iron rollers, being free to expand or contract. The two girder re braced both diagonally and horizontally at intervals, and a foots

way is carried out on each side by cantilevers, having a plain iron railing.

The total weight of the foundations and of the iron girder superstructure on each well was 420 tons, and the area of the bottom of each well was 117 feet, so that the weight was less than 4 tons per square foot

These Bridges are certainly not remarkable for beauty, but their peculiar economy of construction renders them valuable as examples to the Engineer.

No. CCXLVII.

DRAINAGE OF BOMBAY.

(2nd Paper.)

Report on a Project for the Drainage of Bombay. By CAPT. HECTOR TULLOCH, R.E.

The next point which will require consideration is whether rain and sewage should be removed by the same channels, or whether they should be separated. In a Report on the Drainage of Madras, submitted to the Madras Government in 1865, I endeavoured to show that the expense of sewering a town in India on the principles usually adopted by engineers in England would be enormous. Instead of repeating the arguments again, I take the liberty of forwarding a copy of that Report, where in pages from 82 to 90 they can be read.* Since that Report was written, I have had the opportunity of studying the different systems of drainage which have been carried out in the countries of Europe, and I feel more than ever convinced of the necessity of separating sewage from rainfall The London sewers are built to remove both sewage and rain, and the rain was taken at one quarter of an inch in 24 hours On these data, the rain amounts to as much as the sewage, so that one half of each sewer is required for rain and the other half for sewage † In Bombay on the 9th of August last, we had a fall of rain amounting to upwards of 14 inches in 24 hours. Let me, however, take for India the moderate fall of 5 inches in 24 hours. Then, if in London, where the water supply is above 40 gallons per diem per head of the population, the rain, with a fall of one quarter of an inch in 24 hours, is equal to the

* See No. CXXXIX of these Papers

† *Vide* page 306 of "Neville's Hydraulics," second Edition

sewage, it follows that in Indian towns with a fall of 5 inches in 24 hours and a water supply of, say, 20 gallons per diem per head of the population, it would be about 40 times as much as the sewage. So that virtually one-fortieth part only of each sewer would be required for the sewage and thirty-nine-fortieths of it for rain And as falls of rain of 5 inches in the day do not occur except twice in a year or so, and yet would have to be provided for, the sewers in Indian towns, to be effectual in removing the rain, would require to be nearly 40 times as large as they need be for sewage only, and would not have to act to their full discharging capacity except on the average of once in six months

In Bombay, I would propose to effect a complete separation of rain from sewage. The sewers would not consequently have to deal with a variable quantity of matter dependent on the amount of rain during the day, but with a fixed amount of sewage according to the habits of the people. Thus, the normal state of the sewers would be to be constantly charged with sewage,—constantly acting nearly to their full capacity.

Large sewers, when empty, as the sewers of Bombay would be if they were constructed for rainfall, would during the dry months be large cesspools. A small body of water has a much greater evaporating surface in a large sewer than in a *little* one, more noxious gases escape and the inhabitants become poisoned with them.

From a pecuniary point of view I do not see how it will ever be possible for any Indian town to carry out a complete system of underground drains to remove such heavy rains as fall in the country. To provide every street in Bombay with a sewer for rain (and this is the practice in Europe) would cost the Municipality not less than two crores of rupees, *i e.* £2,000,000. It would simply be waste of time to prepare a project on such a scale Indeed it will be hopeless to expect that any large sanitary works will ever be carried out in the country, if the usual principles of drainage adopted by engineers in England are rigidly adhered to. The mere fact that the London Drainage scheme is based on the assumption that only two-fifths of an inch of rain falls over the town in 8 hours, should show the aspect of the question in its true light as soon as we come to apply the principles to Bombay, where only three months ago, there was a fall of rain over the town amounting to more than 14 inches of rain in 24 hours. It cannot, moreover, be urged, as it may be in England, that all heavy storms are merely local, and therefore

should not be considered in drainage schemes Every one who has been in India but a few years, knows that one of the great characteristics of the monsoon is that it is never confined to one small locality When the monsoon breaks over a town it is almost certain to be raining equally hard not only over the entire area of it, but over the surrounding country for miles distant.

Under these circumstances, I maintain that the only way in which it will be possible to drain Indian towns of heavy rainfalls, so as to bring the cost within the means of Municipalities, will be by the help of a *few* main underground channels, and by dispensing with these works in all the minor streets—letting the water escape from them along the surface of the roads. I believe Bombay has already a sufficient number of underground drains for the removal of rain. All that I propose to do is to extend the main drain to the Pumping Station at Love Grove This main drain will actually be capable of removing more than 14 inches of rainfall over the town in 24 hours, and the engines on the other hand will be able to pump nearly the whole of this into the sea during the same time Thus the state of things which occurred on the 9th of August last, when some of the houses in the town were three feet under water will be rendered impossible. In fact the town will probably never be under water at all, and this irrespective even of tides.

The main drain, moreover, would have an overflow on to the Flats, so that if the water beat the engines, or, in other words, if there were, at some very critical period of the storm, more water brought down to the station than the engines could deal with, the overflow would come into operation and the surplus water would be passed on to the Flats, to wait there till the tide went down, when the sluices would be opened and it would run into the sea.

Should there be any water in the town which could not enter the main drain, on account of the latter being quite full, such water would pass on to the Flats, as it now does, by the natural valley line But such a case is not likely to occur, and I would not therefore recommend the construction of any new large drains for rain water till the effect of the proposed works can be judged of I believe the town will be perfectly dry, even when 14 inches of rain fall in 24 hours. For greater storms, I think, it will be admitted by all, I could not justifiably provide. The emergency might not occur in two or three generations.

Only to give an idea of the cost of large sewers, I may mention that one of the heaviest items in the estimate for the proposed works is the continuation of the present main drain, 20 feet wide and 10 feet high, to the pumping station. The distance is rather more than a mile and a half, and the cost will be about eight lakhs of rupees. A few works of this nature would swell the cost of any project to such an extent as to render its practicability out of the question. I do think they are uncalled for Let as much rain as possible escape naturally to the Flats to be discharged into the sea by the sluices, and let only so much be pumped as will keep the town dry

It should be borne in mind that every extension of the town and consequently of the sewerage works will render the treatment of floods easier A greater number of engines will have to be erected for the increased amount of sewage, and these, at times of emergency, can be employed for the relief of the town and island from floods Thus as the town grows older, more and more power will be brought to bear for the removal of rainfall. The project will become more perfect, and a flood be ultimately rendered quite impossible.

If it then be decided, as I propose, to separate rainfall from sewage, and to treat the two differently, the sewers and pipes for the removal of the latter will be of reasonable dimensions. The main sewer, where it is largest, will be only 8 feet 6 inches high by 5 feet 8 inches wide, and it will be of this size for only two-thirds of a mile By far the larger portion of the island may be drained simply by earthenware pipes. On the plan the directions, sizes, slopes, and other information regarding the works may be obtained The sewers have been put at such a depth below ground as will give slopes to the earthenware pipes which will keep them clear of deposit.

There is a question here which demands attention It has been maintained by some, that the sewage of Indian towns will always be thicker than that of towns in England, because rain is admitted into the sewers of the latter, while, even if it were so into those of the former, still from the long continuance of dry weather, there would be many months of the year when the sewers would only be filled with the waste water from the houses. Now though it is quite true that the more water there is the more liquid will the sewage be, still it must not be forgotten that the addition of rain to sewage entails also the addition of the very matter

with which most sewers are found to be choked up. It is not light substances such as house refuse of all kinds of which the deposit consists, but it is almost entirely composed of sand, gravel, clay, &c, and these are washed into the sewers by the rain Light substances float on the surface, and thus pass on to the outfall, while the road detritus sinks at once to the bottom and accumulates there I feel certain therefore, that there will be very few obstructions in the Bombay sewers as compared with those which occur in the English ones

However perfect works may be in theory, something will occasionally happen to prevent them from acting properly in practice Provision should, therefore, be made, not only for ascertaining when an obstruction occurs in a sewer, but also for removing it In England, the usual practice is to put manholes at about a hundred yards apart In Bombay I propose to put them only 200 feet apart The facilities for examining the works under ground will be much increased. By the help of a lamp, the position of an obstruction will be easily ascertained, and in order to remove it, flushing will have to be used.

For the sewers I would employ the same means of flushing as that adopted in England, where the practice is to form a temporary dam in order to let the water collect above the obstruction, and, when a sufficient body of water has been obtained, to remove the dam suddenly. I think this will answer every purpose in Bombay But for the earthenware pipes, I propose to make arrangements by which every manhole may, as occasion demands, be converted into a flushing reservoir. Suppose there is an obstruction in a pipe, then the mouths of the pipes at the bottom of the manhole above the obstruction will be closed, and the manhole filled with as much water from the nearest Vehar main as may be considered necessary. The mouth then of the pipe to be flushed will be suddenly opened by a lever from the surface of the street, and the water will rush with great velocity to remove the obstruction. I feel confident that very few obstructions will ever occur which cannot be removed by these means. Should it, however, become necessary at any time from the fracture of a pipe or other accident to dig down to the work, the proposed short distance between every two manholes will enable the workpeople to ascertain with great precision the exact position where the damage has occurred. Consequently, no labour will be thrown away or useless expense incurred in digging up more of the street than necessary.

There is no doubt that the perfect ventilation of sewers has not been effected up to the present. The charcoal system is, however, admitted by most engineers to be the best Until some more successful plan is discovered, I propose to disinfect the Bombay sewage by charcoal ventilators, one of which will be put down at every manhole.

The house drainage of Bombay will not be nearly so difficult as that of other Indian towns. Between every two houses in Bombay, there is usually a narrow open passage for drainage. I propose to lay the new house drain under this passage, and to connect it, at one end with the sewer in the street, and at the other with the pipe which now brings down the waste water from the upper stories of the house In those few cases where "back drainage" can be adopted, this should of course be done

Wherever water is used in a house, I should insist on a proper sink, with perforated holes in it and with a syphon trap, being put down. This would effectually prevent large substances passing into the pipes to choke them up, and would at the same time keep the noxious gases from entering the rooms. A ventilating pipe connected with the house drain, would be carried up above the roof of the dwelling. All house drains, without exception, would be six inches in diameter.

I have some difficulty in approaching the question of the removal of excreta. This portion of the drainage of a town is so intimately connected with its water supply, that it is impossible to treat it successfully by itself. The fact is that drainage and water supply are really one question only. To separate the two, by considering each apart, will render both defective. Yet if I touch on the subject of excreta, I shall have to do so without a sufficient knowledge of the intentions of the Municipality regarding the future water supply of Bombay There is, no doubt, a scarcity of water at present. The town should not rest contented with a supply of less than 30 gallons per diem per head of the population. When this supply is obtained, I would recommend the introduction of water closets. I must guard myself against the supposition that these closets would be similar to those used in England. Such closets would not at all suit the habits of the people I would have closets of a much simpler kind, and so constructed as not to be liable to injury from those who use them. I should hope, too, that the habits of the people, under better sanitary regulations, would ultimately lead them, though it might

be very gradually, to see the advantage of keeping their closets clean, and the introduction of the European water closet, at all events among the better classes, would be rendered possible

Of course it would be out of the question to put up closets at present while the supply of water to the town is so limited Abundance of water for closets is a *sine quâ none*, but I think a lengthened discussion of the subject at present would be only premature

It really does not matter for the purposes of this project how the excreta may be disposed of If it is found best not to let it go into the sewers, the sewers will still have their work to do, viz the removal of all the waste water in the town. But, on the other hand, if it be decided to discharge the excreta into the sewers, the sewers will convey it away out of the town in a few hours, and it will be utilised on land.

Under the new state of things, that abominable system of opening the sewers which at present exists in all parts of the town, will be entirely done away with There will be no matter in the sewers that will require removal. Everything will be carried to the pumping station, pumped up there and sent on to be utilised on land. Nor will there be any necessity to continue the present system of open drains. I think all sanitarians will agree with me when I say that the chief cause of disease at present in Indian towns arises from our letting the waste water run in open channels. It is impossible to keep these drains clean, for the simple reason that it is impossible to prevent people throwing their rubbish into them. It is the action of the water on the vegetable and animal matter in the drains that gives rise to the foul smells in the streets. Everywhere around one, decomposition is in rapid progress. Under the new system, there will be no open drains, and the foul substances which at present ferment under the action of water, must at the worst lie in the street, where they will either soon be converted into dry rubbish by the action of the sun, or be removed by the scavenging department to the street receptacles for filth. The heat of the sun deprives all substances of moisture—in fact desiccates them, and it is well known that matter in this form is comparatively harmless, whereas the same matter lying in water becomes a constant source of disease.

I would have all the open drains gradually broken up and filled in with road material. At the same time, the section of the streets would be improved They could not be of a better form than that already adopted

in many parts of the town, where the sides of the road are finished off with a slight scoop, and a curb stone separates the carriage road from that for pedestrians

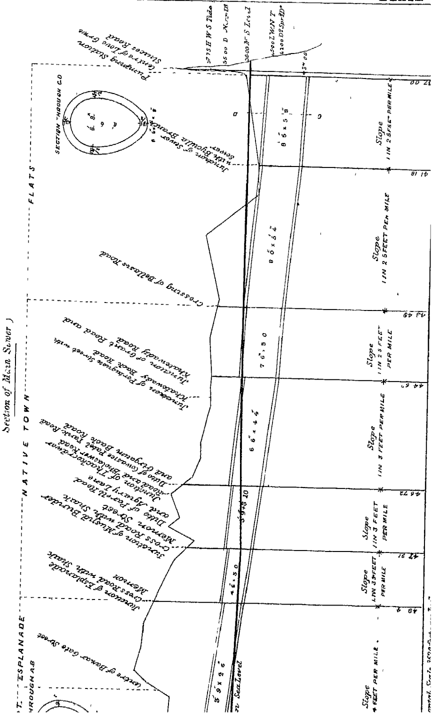
The rain which falls on the town will escape in this way It will first run along the sides of the roads until it enters a street where there is one of the present under-ground drains, into which it will pass It will then flow on to the present main drain, which will carry it to the Flats, or the pumping station (as the occasion may require), and will there be either pumped into the sea or allowed to escape through the sluices The main drain, as I have already shown, will be capable of removing more than 14 inches of rain falling on the town in 24 hours

At present, the Municipality spend about a lakh of Rupees a year in cleaning the drains. Under the new system, this sum will nearly all be saved. I have not, however, credited myself with the saving, as I propose that this money, which represents a capital of about 16 lakhs of Rupees, should be devoted to filling up the drains and improving the roads Should a drain for rain water be required in some particular street hereafter, it could be built when found necessary just below the surface of the road, but I do think it would be mere waste of money to erect such works, at present.

Having now completed the general description of the proposed project, it is necessary that I should enter on some particulars in connection with the works themselves.

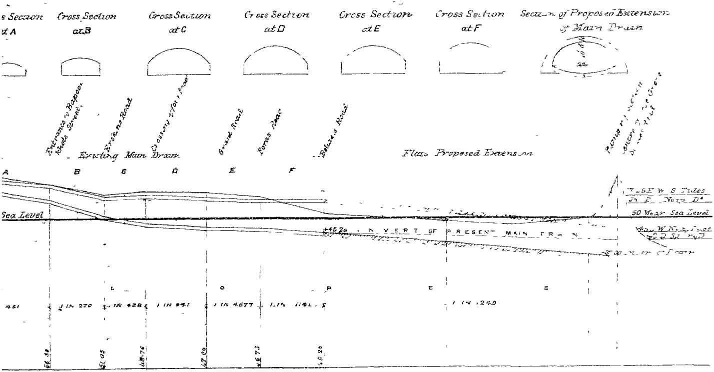
The only part of the thickly inhabited portion of the southern half of the Island which will not be drained by this scheme, is Colaba It is a small locality, and the population can never be great. It would not be worth while to lay down an expensive sewer for so few people, but if this should be required, it could be done by simply extending the main sewer to the south. The main sewer, as proposed at present, will start from the Fort with its invert at 53 above datum. After receiving the sewage of this neighbourhood, it will cross the Esplanade, along the road west of the Dhoby lines, and then enter the town. It will continue its course along the following streets, Shaik Memon Street, Bholeshwar Road, Ardasheer Dady Street, Khetwady Back Road. It will then cross Grant Road and Bellasis Road, and run direct to the Pumping Station, which will be

PLATE



Section of Main Sewer)
NATIVE TOWN
FLATS
ESPLANADE
SECTION THROUGH CD
Pumping Station
Crossing of Bellasis Road
Slope 1 IN 2 5 FEET PER MILE
Slope 1 IN 2.5 FEET PER MILE
Slope 1 IN 2.5 FEET PER MILE
Slope 1 IN 3 FEET PER MILE
Slope 1 IN 3 FEET PER MILE
Slope 1 IN 3 FEET PER MILE
Slope 4 FEET PER MILE
8 6 x 5 3
8 0 x 5 4
7 6 x 5 0
6 6 x 4 4
5 9 x 3 10
4 6 x 3 0
5 9 x 2 6
Sea Level

(Section of Main Sewer.)



Horizontal Scale 1520 feet an Inch
Vertical Scale 20 feet an Inch

situated close to the present one at Love Grove At this point the main sewer will have its invert at 37 above datum At the Fort, with a slope of 1 feet to the mile, it will be 3 feet 9 inches high by 2 feet 6 inches wide, and it will gradually increase as it passes through the town, till it reaches the Flats, where with a slope of 2½ feet per mile, it will be 8 feet 6 inches high by 5 feet 8 inches wide Throughout its course it will be egg-shaped. There will be two branch sewers required, and each will be 3 feet 9 inches by 2 feet 6 inches, and have a slope of 4 feet per mile. The first will start from Mazagon, and join the main near Mombadevy Tank. The second will start from the Parell Road, near Sindalpara, and will join the main on the Flats The more important streets running perpendicularly to the main will be furnished with 12 inch earthenware pipes, and all other streets with 9 inch pipes. Both the main and branch sewers will be built of the best brick

The sizes of the sewers have been regulated thus. Each sewer will discharge rather more than the sewage of the inhabitants living on the area which drains into it Allowing for a much more abundant water supply than Bombay has at present, the sewage is taken at 20 gallons per diem per head, and half this quantity is supposed to run off during 8 hours of maximum flow. The number of people living in the thickly populated parts of the town has been ascertained, as well as this could be done, from the last census returns,* and the possible future population on the thinly inhabited areas is taken at 500 souls per acre

The power of the engines has been calculated in this way. The population has been taken at 1,000,000, and the water supply at 20 gallons per head per diem, half of which has been assumed to run off during 8 hours of maximum flow. In order to send the sewage to a distance to be utilised, it will be necessary to pump it about 50 feet high With this lift, about 315 horse-power (nominal) will be required According to the usual plan adopted in water works, I propose to have three engines each of half the actual power required, or say three engines of 150 horse-power each. Two would be ordinarily at work, and the third as a reserve in case of accidents.

I would have two of the engines of the kind known as rotatory expansive double powered condensing engines The third engine would be a

* The density of some of these is extraordinary—700 to 800 souls per acre The average density is over 600 per acre.

high pressure one, capable in an emergency of being worked up to two or three times its nominal power. This engine would work a large centrifugal pump and would be the principal one employed on the duty of relieving the town of floods. The average lift would be 8 feet. Moving at a high speed, the pump ought to throw a large quantity of water. In place of one high pressure engine, it may hereafter be found more convenient to have two, each of 100 horse power nominal, but this is a point of minor importance at present, and need not be entered into further. The length of stroke, size of pumps, &c., had best be decided upon while the detail plans of the works are being prepared. There should be a filth hoist and a number of other arrangements made, similar to those carried out at the large sewage pumping stations of London. All these details will have to be carefully attended to before the engines are ordered.

As fast as the sewage is pumped up, it will be carried by a 4-foot cast iron main to the irrigation lands, where it will be let on to the fields by the help of sluices. If it could have been done, I should have preferred to build a sewer above ground as recommended by Mr. Rawlinson, in place of laying down a cast iron pipe as proposed by me. But I found that in order to construct such a sewer, I should have to raise an embankment over parts of the island more than 30 feet high. In fact the levels of the ground are so unfavourable for a high level irrigation sewer, that I am certain Mr. Rawlinson will agree with me in this departure from his suggestion, when he learns why I have adopted the cast iron pipe. I will not here enter on the question as to the best mode of applying the sewage, because before the day comes for doing so, there will be plenty of time to make experiments, and these will be a safer guide than any instructions I could give, which would be based on my experience of sewage farms in Europe only.

The present main drain is to be continued from where it stops now near Bellasis Road down to the pumping station. Its form will be altered in order to render the work less costly. It will be nearly semicircular, the diameter being 20 feet. It will have a slope of about 4 feet per mile, and enter the pumping wells at the same level as the new main sewer. The discharging power of the new main drain will be fully equal to that of the old. As it will be required for rainwater only, I propose to build this work with rubble stone.

The proposed sluices at Love Grove, Worlee, and Daravee, each having a waterway of 120 feet in length, may be of the kind now in use, which seems to answer very fairly

In preparing the detail plans, it will probably be found better to make the sluice at Daravee, with a waterway of about 80 feet, and each of those at Love Grove and Worlee with a waterway of 140 feet,—keeping the total waterway the same as before, viz 360 feet long When more levels are taken over the island, the areas that will drain through each sluice can be calculated, and the length of the sluices regulated thereby

The entire cost of this project is estimated at 75 lakhs of Rupees I have gone as carefully into the subject as I possibly can, and I believe if there is any error in the estimate, it will be found to be on the side of excess.

I may perhaps go over some of the more important items for the satisfaction of those who may not care to examine the detailed statement. Brickwork for the sewers has been taken at Rs 90 per 100 cubic feet, excavation at Rs 12, and rock cutting at Rs. 40 Twelve-inch pipes are calculated at 1 Rupee 6 annas, and nine-inch at 14 annas, per foot run. These are higher prices than the Municipality have paid up to the present The excavation for the street drainage has been taken at Rs 8 per 100 cubic feet. The cuttings will not be so deep as those required for the sewers The engines have been estimated at Rs 1,200 per horse-power, and a lump sum of Rs 3,00,000 has been put down for the engine and boiler houses

The irrigational part of the scheme will consist chiefly in the laying down of cast iron pipes, which have been calculated for at Rs 120 the ton. About 8 lakhs have been allowed for the purchase of land for sewage irrigation, which lies several miles from Bombay.

The rubble for the Main Drain has been taken at Rs 50 per 100 cubic feet.

Each sluice, with a waterway of 120 feet in length, has been estimated to cost $1\frac{1}{2}$ lakhs.

Ten per cent, or nearly 7 lakhs, has been added to the total cost of the project to allow for all contingencies

I am told that the rates I have taken are unnecessarily high If I chose therefore to make the project more attractive, I could do so by reducing the estimate to about Rupees 68,00,000. I prefer however to let

it stand as it is. I would rather err in having exaggerated, than in having under-estimated, the cost

This project will no doubt be compared by many people with those which have already been submitted to the Municipality In order to form a fair judgment in the matter, it should be borne in mind what is intended to be done by each I believe this will be found by far the cheapest scheme yet proposed for the drainage of Bombay, but I should be the last to urge that it should be adopted merely on that account. Of course every project must be looked at from a pecuniary point of view. The cheaper it is the more advantageous must it be for the inhabitants. But mere cheapness should never be its sole recommendation Its sanitary and engineering advantages should also have due weight. The following are the main objects to be effected by this scheme I beg those who may have done me the honor to read this report to compare these objects with those contemplated by other projects —

1st.—This is not a project for main drainage only, but for the entire drainage of Bombay from rain and sewage,—for all works complete nearly up to the door of every house.

2nd.—The town is to be immediately relieved of floods, even during storms when 14 inches of rain fall in 24 hours I believe no city in Europe, and if I add in the world I shall not perhaps be wrong, has yet attempted to deal with a rainfall approaching these limits.

3rd.—The entire island is to be relieved of floods after similar storms of 14 inches of rain in the day, so that within 24 hours after the close of the storm, there shall be no swamps to be found anywhere

4th.—From being a foul and pestilential swamp, a receptacle for the filth of the town, a constant source of disease to the inhabitants, and the greatest nuisance in Bombay, the Flats will be converted not only to a useful, but even to a healthful, purpose.

5th.—That which gives Bombay its chief importance, and must ultimately make her the capital of India—her magnificent harbour—will be preserved from sewage pollution. Thus the drainage of the town can never in any way detract from its maritime advantages

6th.—Instead of being thrown away as worthless, the sewage will be utilised on land. Thus, what is rightly termed a "source of wealth" by the leading scientific men in Europe, will be secured to the inhabitants

7th.—In whatever direction the town may spread, the new districts can

be drained so that the works required for them will fit in at once with those already proposed for the present town Thus Bombay, increase as she may, will always be drained on one comprehensive plan and not by a series of patchwork systems, each unconnected with the others

8th.—The Municipality will have the sewage so completely under command, that they will be able to utilise it as recommended by Mr Rawlinson, or to discharge it into the sea at any point on the coast of the island at a cost not exceeding that of this project Thus the disposal of the sewage will in no way affect the works of drainage and sewerage If these are the best in themselves that have yet been proposed for the town, they need not be delayed on account of any doubts there may be in the minds of the Municipality with regard to the success of sewage utilisation.

In conclusion, I beg to add that no one can be more sensible than I am how imperfectly I have been able, in the short time I have been engaged on this work, to do justice to Mr. Rawlinson's scheme The more the general principles of that scheme are considered, the greater conviction will they carry to the mind that Mr Rawlinson's propositions are the best that have yet been made for the drainage of this important town. Now that the scheme for utilising the London sewage has been temporarily given up for want of funds, in consequence of the depressed state of the money market, I believe that if this project is quickly carried out, Bombay will be the first city in the world with a population of a million inhabitants that will have utilised her sewage on a systematic plan In fact she will have set Europe an example in the adoption of those principles which, although they have been advocated for years by the leading engineers of England, and by the most scientific men on the Continent, have yet never been fully acted upon in any one city in the world

I beg to thank all those who have assisted me with information or suggestions in the preparation of this project, and especially Mr Thwaites, C.E., the present Resident Engineer, Bombay Main Drainage, whose acquaintance with sewerage works generally, and with those of Bombay in particular, has been of great service to me.

H. T.

Abstract of Estimate.

		RS	RS
Sewers, ...	Brickwork, .. .	6,41,970	
	Excavation, ...	4,60,944	
	Rock-cutting, . .	88,320	
			11,91,234
Street Drainage,	12-inch Pipes, ...	1 08,900	
	9 do do , .	2,54,100	
	Excavation for Pipes,	7,98,336	
			11,61,336
Manholes, ...			4,11,000
Pumping Station. .	Engines,	5,10,000	
	Engine House, Boiler House, &c , . . .	3,00,000	
			8,10,000
Extension of Main Drain, ...			7,65,475
Sluices, ...			4,50,000
Outlets to Sea, ...			30,000
Sewage Utilization,	Pipes and Valves, &c ,	12,69,094	
	Land, ...	7,26,000	
			19,95,094
			68,14,139
Add 10 per cent. for contingencies, ...			6,81,414
Grand Total Rupees, . .			74,95,553

or say 75 lakhs of Rupees

No. CCXLVIII

TIMBER TREES OF THE NULLAMULLY HILLS.

To the Editor.

DEAR SIR,—As I suppose your Journal is intended for the information of the three Presidencies, I send you the following list, as the information may not only be interesting to those in the sister presidencies, but may lead to further enquiries and an extended list of the woods in India, which when obtained in a collective form, would be useful to everybody engaged either in the Public Works, or Contracts, or to private persons I am sorry I cannot send you the specimens, as these are in the Kensington Museum, and upon my coming to India, I did not think it advisable to get them In making the collection, I appended a leaf (dried of course) and a piece of bark,—the wood rough and polished,. my researches would have gone to weight per cubic foot, and specific gravity, but time did not permit.

P S.—The Nullamullys are a range of hills in the Bellary District, Madras. I shall be able to send you hereafter an account of the Timbers in Shemoga and Coorg Districts

List of Timber Trees of the Nullamully Hills in the Madras Presidency. By GEO. LATHAM, ESQ, M I C.E, Ex Engr. P.W D., Calcutta.

Locality	No	Botanical name	Telegu.	Authority.	Remarks by writer
Kurnool,	1	Ulmus integrifolia.	Namille or Nowlee,	Balfour,	A light-colored, close grained wood, used for general purposes

Locality	No	Botanical name	Telegu	Authority	Remarks by writer
Kurnool	2	None,	Roodia Genapa,	Balfour,	A light, porous wood of little use.
"	3	Pterocarpus Marsupium,	Tegzee,	"	A darkish, coarse-grained, serviceable timber.
"	4	None,	Palavaraynee,	"	Wood, light yellow, hard and is I think the "*Pedakal mesuoa*" of the Northern Sircars
"	5	Mangifera Indica,	Mamidi chettu,	"	Mango wood, useful for temporary purposes
"	6	Canthium parviflorum,	Balusu,	"	Called at Kurnool "Beerchanapech," a dark good wood of serviceable character.
"	7	None,	Nella Poleki,	"	A light wood of coarse grain, unserviceable except for temporary purposes.
"	8	Cathartocarpus Roxburghii,	Uskiamen or Uri widdee,	"	A light, strong, hard, wood, very useful
"	9	None.	Terra Poleki,	"	A red, hardish wood, generally useful
"	10	Gmelina Arborea,	"Goomertek" or Gumudateku,	"	A hard, durable wood called at Kurnool "Gooteky"
"	11	Pterocarpus Santalinus,	Chandan,	"	A beautiful hard, red wood (valuable)
"	12	Chloroxylon Swietenia,	Bilugu,	"	This is called "Bilu" at Kurnool and is a very poor sort of satin wood and used commonly.
"	13	Bauhinea racemosa,	Arree,	"	A dark reddish brown close-grained wood, called at Kurnool "Kodaree" used in beams.
	14	Terminalia Belerica,	Thanddee,	"	A serviceable wood, chiefly used for posts, color yellowish brown, close grained.
"	15	Odina Wodier,	Goompana chettu,	"	A soft, light, reddish wood, useful for general purposes
	16	Nauclea parviflora,	Butakarramee,	"	A hard, tough wood, light red in color, used for yokes, posts and small beams.

Locality	No	Botanical name	Telegu	Authority	Remarks by writer
Kurnool,	17	Acacia Arabica,	Tuma,	Balfour,	The Tamil name is "Kuruvalum" and Hindostani name Babool.
,,	18	Acacia Suma,	Tella chandra,	,,	A very good, strong, dark red wood, used generally and for agricultural implements
,,	19	Maba buxifolia,	Nulla Muddee,	,,	A hard sepia colored wood, used for general purposes.
,,	20	Acacia leucophlœa,	Tella tumma,	,,	Tamil name "Velvaila" a hard light colored wood streaked with brown, used for various purposes, a liquor used by the Natives is extracted from the bark.
,,	21	Azadirachta Indica,	Tepa or Teefa	,,	Tamil name "Vaypum Murum" The mugosa tree is a very useful wood, used generally by natives in house work.
	22	Syzygium jambolanum,	Nerar,	,,	I think this is the Tamil "Nawel Nurrum", it is called "Neraide' in Kurnool and is a useful wood, light sepia color and medium hardness, used generally in planks.
	23	Lagerstrœmia parviflora,	Chinna Nagee,	,,	A light brown, compact hard, serviceable wood, used generally
	24	Gmelina Asiatica,	Gumudee Chettu,	,,	A hard wood of yellow color, useful
,,	25	Tectona grandis,	Tek,	,,	Tamil "Tek Murrum" The Teak tree, the most useful wood in India
,,	26	Gardenia latifolia,	Bikkee,	Ell.	A light yellow wood of little use, native combs are made from it
,,	27	Capparis grandis,	Regutti,	Balfour,	A light sienna colored wood, close-grained and hard, of medium weight and a useful timber
,,	28	Dalbergia latifolia,	Littigee or Terru Gudee,	,,	Tamil name "Eroopooloo" the rose wood of India, a dark, mottled wood, very useful but heavy.

Locality	No	Botanical name	Telegu	Authority	Remarks by writer
Kurnool,	29	Hardwickia binata,	Nar yapa,	Balfour,	A very dark heavy wood red in color, used in long beams, it is often hollow through the heart.
"	30	Erythrina Indica,	Barchanapa or Baju-pee Chet-tu,	"	A common, close-grained, light colored wood, used in building native houses, it is also called *"Moochy wood"* Brown's Dictionary calls it "Bastard Teak" The latter term *"Chiri tek"* is applied to several large trees with large leaves On the Nagari hills, the *"Tanadis"* give it to Dillemia (now "Wormia bracteata") see Wight's "Icones plantarum India Orientalis."
	31	Diospyros Melan-oxylon,	Tunkee or Tookee,	"	A very good, close wood, the centre generally black and heavy, when large, a very serivcable timber.
	32	Careya arborea,	Budadarinee,	"	A very useful timber, dark red in centre, yellow outside, used for large beams.

July 7*th*, 1869. G. L.

No. CCXLIX.

PRESTAGE'S IRON EXPANDING PILES.

Note on Experiments with Wrought Iron Expanding Piles, formed of old Railway Metals. By FRANKLIN PRESTAGE, ESQ.

THE first experiment was made with a Pile 24 feet long, formed of two rolled II Irons, weighing each 24 lbs. to the foot (See Drawing No. 1) The Pile, with the stop bar secured in place, was driven by a 17 cwt. Monkey, 12 feet into soil composed of clay and silt, it (the Pile) being loaded with 30 cwt. of Pig Iron to act as a persuader The stop bar was then raised, and the Pile driven another foot, when it was found the wedge had only sunk 6½ inches, so that the Pile had gained on the wedge 5½ inches (the amount of play allowed the links by the slot in the wedge) The Pile was then driven another 4 feet, but only gained on the wedge 1¼ inches Between the 17th and 18th foot it gained 3½ inches; between the 18th and 19th foot, 5½ inches, and between 19 feet and 19 feet 8 inches, 5 inches; which proved the Pile had gained 1 foot 9 inches on the wedge, or sufficient to bring the links horizontal, and that the wings had fully expanded, upon which the ground was carefully opened, that the form taken by the wings whilst expanding might be observed. It was found that the wings had expanded to the full extent allowed by the links, but the main members of the Pile (the II Irons) had also spread to a much greater extent than was intended, and that they were 1′.7″ apart at the bottom. This would have given some additional supporting power, but it also caused the upper part of the expanding wings to be 16 inches apart, which again resulted in the wings standing at an angle of

'3° instead of 66°, and by which they presented a bearing surface of ›nly 2·90 feet instead of 3 75. The Pile was then drawn, the main nembers re-set, and to prevent them again spreading to the same ex- ent, a collar was placed round the II Irons immediately above the oints of the expanding wings. This test proved that whilst the stop)ar was in place, there was no great pressure upon it, and that imme- liately it was raised, the main members of the Pile travelled freely over he wedge until checked by the links It also proved that the wings were tept vertical, and truthfully in position until it was desired they should expand It further proved that the outward set given to the bottom of the main members caused them to expand, although to a greater extent than was intended.

Test No. 2—The Pile was again driven 12 feet in the same manner,)ut some little distance from the former site, when the stop bar was aised and a bar let down and screwed into the top of the wedge (sub- sequently suggested by Messrs Ward & Bell as likely to be necessary) A thread was cut on the upper part of this bar by which it was screw- ed up as desired, and by setting up the slack after every blow, it was found that in driving the Pile $5\frac{1}{2}$ inches, it had gained that much on the wedge, and therefore the latter must have remained stationary for the length that the links had play in the wedge. The driving was then resumed, and for the remainder of the $6\frac{1}{4}$ inches required to complete the total of 13 feet, the Pile gained on the wedge $\frac{3}{4}$ inch, to the 16th foot, it gained at as near as possible the same rate, or $1\frac{1}{2}$ inch per foot; from the 16th to the 17th foot, it gained $5\frac{3}{4}$ inches, and from 17 feet to 17 feet 6 inches, it gained $4\frac{1}{4}$ inches, showing that the wedge to- wards the end of the driving was nearly stationary. The mark on the gauge, indicating the exact distance from the top of the Pile to the point where the links would become horizontal, had unfortunately be- come obliterated, and fearing that further driving would start the links if the wings were fully expanded, it was determined to load the Pile to complete their expansion, and bring it to its bearings. It was there- fore loaded with 20 tons, that being the testing load of the 4 feet 6 inches Screw Piles used extensively in the construction of the Eastern Bengal Railway. Between receiving the 12th and 15th tons, the Pile sunk $3\frac{3}{8}$ inches, and then became stationary, and remained so for two nights and a day, when a further load of 4 tons was added, causing a

very gradual settlement of $\frac{3}{8}$ of an inch; when it again became stationary and remained so for several days, when the load was taken off and the ground opened out, and it was found that the wings had fully and fairly expanded and that the main members of the Pile had expanded 18 inches at the bottom. This Pile is still in the position it was tested in This test proved that the wings were in some measure made to expand more quickly by keeping an upwards strain on the wedge by means of the bar tightened from above, but in this case, the Pile was driven from 10 feet to 17 feet 6 inches into loose silt and under water, which no doubt also caused the wings to expand more readily.

Test No 3 —This was made with a Pile formed of two Railway metals weighing also 24 lbs. to the foot each, hooped together as per Drawing No. 2, but the expanding wings instead of being hinged at the top, were securely rivetted to the rails at the top, bottom and sides, two sets of links being used and placed clear of the rails, the Wedge being made to bear on them This Pile was driven in the same way, but when it had penetrated 4 feet, the stop bar was removed, and upon the driving being resumed, it could be seen the Pile was expanding, the lowest collar being above the surface of the ground. After it had been driven 6 feet in all, the ground was opened, that the rate of expansion might be observed whilst the driving was progressing. After the Pile had been driven a total of 10 feet 4 inches, it had expanded to the full extent allowed by the links, and upon raising it to the surface, it was found the metals had a permanent set under the lower collar, and each had gone out equally. This Pile is also lying at Sealdah near the position it was driven in. This test proved that by keeping the Pile vertical (and which there should be no difficulty in doing) the wings go out equally, and that the slight outward set given to the bottom of the rails, and the aid of the wedge, are quite sufficient to cause the Pile to expand

Test No 4.—This Pile was formed of a cluster of eight worn out Railway Metals, (as per Drawing No. 3,) the wings as in the last mentioned Pile not being hinged, but rivetted to the main members of the Pile. This Pile was driven by the same means and in the same manner, no heavier Monkey being available, after it had been driven 8 feet, the stop bar was removed, and the driving continued until it had penetrated a further depth of 7 feet, when the Monkey failed to have any further effect, but the gauge showed the wings had 7 inches to rise to become

horizontal. The Pile was then loaded, and did not yield with 36 tons; upon the load being increased to 54 tons, a gradual settlement of 8½ inches was caused, when it again became stationary, on which it was determined to ascertain the maximum load it would carry, and which was proved to be 73 tons. With this load it toppled over and upon raising the Pile to the surface, it was found that the two Metals carrying one of the Wings had parted close under the lower collar.

This Pile can be seen in its fractured state

Test No. 5.—It being desired that a test should be made with a Pile of the same section as the above, but without expanding wings, one of the same length was driven 8 feet into the ground, and when loaded with 7 tons, it gradually settled until the load reached the ground.

This Pile can be seen in the position it was driven.

REMARKS.

From the foregoing it will be seen there is no difficulty in causing such Piles to expand, and at the point desired, and there cannot, I think, be any doubt as to their sustaining power. That they can be made to penetrate in sand and such soils as are difficult to penetrate, is proved by the fact of a mooring constructed on the same principle, the section of which was 3 feet × 1 foot 5 inches or 4·25 square feet, or more than treble the displacement of the largest Pile described in test No. 4, having been driven in six fathoms of water, 27 feet into that part of the bed of the Hooghly found to be most difficult to penetrate, and where 3 feet 6 inches screw moorings could only, with a great expenditure of power, be sunk 21 feet. The total weight of the mooring, driving tube, and chain amounted to about 5½ tons, and the Monkey used weighed only 2 tons 7 cwt. A trial is about to be made with a similar mooring, the weight of which, including the driving tube and chain, will also be 5½ tons, but the displacement of which will be reduced to 2 square feet (the maximum displacement necessary for any ordinary Pile), a Monkey weighing 5 tons will be used, and it is believed such a Pile can with ease be made to penetrate to any reasonable depth desired.

Mode of Driving.—The Piles can be driven by a Monkey travelling in guide frames in the ordinary manner, and worked by steam or hand power, but the mode recommended is that of letting the Monkey travel up and down on the Pile, thus making the Pile itself the guide. In a

tide way, time and power are economized by using the Barge as a persuader, and making it fast to the Pile by Screw couplings, which should be screwed up at every blow given by the Monkey, by this means the Pile should be driven 40 feet through the most compact sand in a single tide

Cost—Here will be found the great gain in using such Piles. I have proved they can be formed of old Railway Metals, and it is found with Piles 60 feet long (say 20 feet into the ground in 20 feet of Water, and allowing for 20 feet of head way) that 95 per cent of the material forming the Pile, if of old Rails, should be purchased @ £5 per ton, the remaining or specially imported material, forming the remaining 5 per cent, costing £29 per ton, whereas Wrought Iron Screw Piles in Calcutta cost some £37 per ton.

This is the main gain, but there are others.

1st—The Plant and appliances required are of the cheapest and most ordinary kind, such as any good Ship Carpenter can manage, only sufficient tackle being required to pitch the first length of Pile, so that the joint is above water, after which Rail after Rail can be added, and fished and hooped as desired

2nd,—The bulk of the labour required is of the most ordinary kind, and abundance of it in the shape of Native Platelayers can be obtained on the Railways

Compared with Screws, the saving of time and power in sinking is very great indeed Instead of displacing soil equal to the area of the screw to get the same bearing surface, only $\frac{1}{8}$th the area is displaced.

That portion of the shaft of the Pile which is in the ground, is supported by solid instead of disturbed earth.

The cost of the Piles per ton would diminish, instead of increase, as the size is increased, and there is hardly any limit to the size that it would be possible to construct them; I may here mention that by fishing and breaking the joints, as should be done, the same strength throughout may be got with any Pile of reasonable length.

At the suggestion of an officer of Government, the experiment of constructing the superstructure of an ordinary Road Bridge also of old Rails was tried; such a Bridge as that shown in Drawing No 4 was erected having a span of 38 feet, width of Roadway 15 feet, the calculated safe load of which is 10 cwt. to the foot run. The Bridge was

as rigid as could be desired with this load, and it is thought to be a most useful class of structure for Feeder Roads to Railways.

It is estimated that 15,000 tons of Rails per annum will in the course of a short period be worn out on the Railways under the jurisdiction of the Government of Bengal, and the question therefore of utilising the large quantity of old Rails that will soon be in the hands of the Railway Companies, must at an early date receive the attention of those Companies' officers.

The average price realized for old Rails in England, is half the market price of new, or about £3 per ton. It therefore will not pay to re-ship them to England, and it is very doubtful if they could be re-rolled at a profit in this country. It therefore will, I should think, be very much to the interest both of the Government and the Companies, if £5 per ton can be realized for them on the spot, and more particularly if they can be turned to such good account as that of being the means of making cheap Bridges for Railway extensions, or Roads

Not having the time to give this subject the attention it appeared to me to deserve, I forwarded to England the design for the Pile before the tests were made, and took the opinion of two sound Engineers as to the class of structures such Piles would be suited for, attached to this are the opinions of the Engineers in question, together with sketches and estimates of structures of various spans

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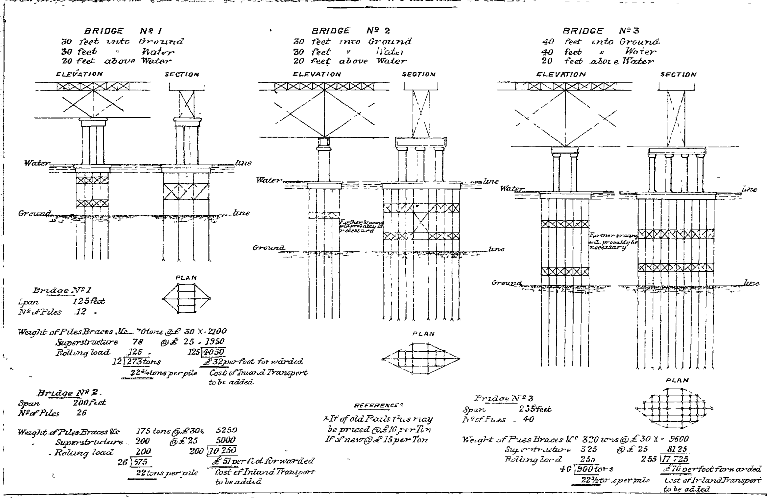
REMARKS ON MR. PRESTAGE'S PROPOSALS BY MESSRS. WARD AND BELL, CIVIL ENGINEERS.

Expanding Pile.—It is very doubtful whether any reliable conclusion as to the action of these Piles could be arrived at by reasoning, independently of experiment. It may be conjectured that before the wings would expand by driving, they would require to be opened to some extent by some other means. This is intended to be done slightly by the expanding of the II irons, but might if necessary be effected to a greater degree, by the stop bar being screwed at the bottom into the wedge, and lifted up forcibly which would raise the wedge and expand the wings after which it could be unscrewed and drawn off. If the wings should be found too large, they might be reduced considerably; several sets of them might be placed on alternate sides of the Pile at different levels, say 4 feet apart vertically; each set might then be suc-


BRIDGE No 1
30 feet into Ground
30 feet " Water
20 feet above Water
ELEVATION
SECTION
Water line
Ground line
PLAN
Bridge No 1
Span 125 feet
No of Piles 12 .
Weight of Piles Braces, &c. 70 tons @ £ 30 X . 2100
Superstructure 78 @ £ 25 . 1950
Rolling load 125 . 125 | 4050
12 | 273 tons
22¾ tons per pile
£ 32 per foot forwarded
Cost of Inland Transport to be added
BRIDGE No 2
30 feet into Ground
30 feet " Water
20 feet above Water
ELEVATION
SECTION
Water line
Further bracing will probably be necessary
Ground line
PLAN
Bridge No 2.
Span 200 feet
No of Piles 26
Weight of Piles Braces &c 175 tons @ £ 30 x 5250
Superstructure 200 @ £ 25 5000
Rolling load 200 200 | 10 250
26 | 575
22 tons per pile
£ 51 per foot forwarded
Cost of Inland Transport to be added
REFERENCES
*If of old Rails this may be priced @ £ 10 per Ton
If of new @ £ 15 per Ton
BRIDGE No 3
40 feet into Ground
40 feet " Water
20 feet above Water
ELEVATION
SECTION
Water line
Further bracing will probably be necessary
Ground line
PLAN
Bridge No 3
Span 235 feet
No of Piles 40
Weight of Piles Braces &c 320 tons @ £ 30 X = 9600
Superstructure 325 @ £ 25 8125
Rolling load 255 255 | 17 725
40 | 900 tons
22½ tons per pile
£ 76 per foot forwarded
Cost of Inland Transport to be added

cessively expanded by acting from the top of the stop bar, which could then be drawn out and a small amount of driving would complete the expansion and give the Pile its maximum power of resistance This action, however, will depend so entirely on the nature and uniformity of the ground, that experiment alone can decide as to its fitness.

A long Pile would be liable to bend in the middle when loaded, and it is doubtful whether a simple collar embracing the II irons would give sufficient stiffness With long piles it might be necessary to make the middle portion of the Pile of box girder section, or of some other section of considerable transverse stiffness, such Piles acting as above described would be driven to great depths with much greater facility and with more economy of material than Screw Piles, whilst they would probably bear as much per square foot of area.

Superstructure of Bridges—It may be observed that the height of a viaduct being given, the number of spans should be arranged so that the cost of the superstructure, less the flooring, for one span, shall be equal to the cost of one pier.

The cheapest kind of superstructure for single line Bridges, consists of two main girders, one directly under each Rail, and supported by the Piles as directly as possible. They are bound horizontally at top and bottom, and also transversely, and covered with planking on which the longitudinal Timbers and Rails are laid. For small spans, plate girders are found to be the best and cheapest, while for spans of 60 or 70 feet and upwards, Warren or Trellis girders are more economical. The practical difficulties of bracing under water may be overcome up to, say about 36 feet, but we think that beyond that, the difficulty would be very great and would require further consideration

Annexed are rough sketches and estimates of cost of Iron Bridges with the expanding Piles, based upon the assumption that the safe load upon one of the expanding Piles of 200 lbs. per foot forward is $22\frac{1}{2}$ tons, being $4\frac{1}{2}$ square feet $= 5$ tons per foot Super

R. J. Ward,
William Bell,

February 25th, 1868.

11 *Great Queen Street*,
Westminister,

No CCL

CONCRETE ARCHES FOR BRIDGES.

Memorandum upon the use of Concrete Arches for Bridges, in the Central Provinces. By C. CAMPBELL, Esq., *Supdg. Engineer.*

The subject of Concrete Arches is one which has occupied my attention for some years past, it having been first drawn to it in 1860, by finding that the roofs of the old native buildings, in which the troops at Delhi were temporarily cantoned, had been standing for many years, (probably for more than a century) without the vestige of a support under them. These roofs were constructed about the middle of the 17th century (when the modern city of Delhi was founded by Shah Jehan), and were carried upon sâl beams and burgahs in the usual manner Over the burgahs were set two or three layers of thin bricks, and over these, a coarse concrete of kunkur, lime, unburnt kunkur, and broken brick was laid, for 2, 2½, and even 3 feet, the whole being thoroughly well beaten and consolidated. When I examined these roofs, I found that both the beams and battens consisted of a mere shell of sound wood, ⅛ inch thick, filled with dust and touchwood; and, as they must have been in this state for more than a century, it follows that during that time the concrete had been kept up by its own cohesion. The span of these roofs varied from 18 to 24 feet.

It was, of course, too great a risk to leave a regiment of British Infantry under such roofs, and they have all been since removed, the same course having been adopted at the Dewan-i-Am Barrack in Fort

Lahore, where a similar state of affairs was found to exist three or four years ago.

Last year, when in charge of the Lahore Circle, I had several discussions with Lieutenant James Browne, R.E., Executive Engineer of the Kangra Valley Road, on the subject of using more economical materials in bridges, and amongst others, he suggested the use of concrete arches. As Concrete is a vague term, its quality varying in every district with the lime found there, I requested him to make a series of experiments, with a view to ascertaining, (1) the best shape in which to use it, (2) the best proportion for its component parts, (3) its behaviour under the tremulous motion imparted by a moving load, and (4) its behaviour under extreme variations of temperature, which, I may remark, are very great in the Kangra Valley As regards the first of these points, it is evident that a concrete arch is not a true one, but merely a curved beam; and it was a desideratum to find out what shape best secured the greatest amount of strength Its behaviour under tremulous motion might be guessed from the conduct of the mortar joints in a brick arch under similar circumstances, but it was as well to ascertain whether its use in a large mass might not cause it to be differently affected. Lastly, the expansion of concrete (which, from the experience gained recently during the erection of concrete houses in England and France, is found to be considerable,) threatened to render its use in arches decidedly objectionable, unless it should prove that in a curved girder, fixed at both ends, and therefore rising and falling at the crown only, the elasticity of the material would permit of considerable expansion without fissures and cracks being caused thereby It should be added that concrete in England is generally made with cement, which I believe expands more than ordinary lime

Owing to his transfer to another division, Lieutenant Browne has not had time to complete these experiments, but he has favoured me with the result of them as far as they have gone, and I here transcribe his interesting account, premising that his lime is very similar to that used in the Jubbulpore Division, the best being procured from limestone boulders of a purple colour, washed down from the adjacent main chain of the Himalayas, while another sort is procured from a local deposit which occurs in detached beds in the Siwalik range, and which

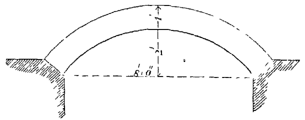
is similar in quality to that usually found in the neighbourhood of Jubbulpore —

Extract of letter from Lieutenant Browne

I have been making a pretty extensive series of experiments on concrete arches, as you directed, and these are the results in the rough

(*a*). Centerings all removed three days after completion of the arch, this time seemed quite sufficient in every case.

(*b*). All arches 1 foot 6 inches wide, and as below.—



(*c*). The arches were simply ribs, segmental in shape, and were not built up with any backing whatever

(*d*). All ribs tested one month after completion, and by placing a concentrated load on the crown.

(*e*). Breaking load, under which the ribs yielded when concentrated at the crown, was as below in each case. ingredients being by measurement, not by weight.

	Lime	*Sand.**	*Soorkhee.*	*Broken granite.*	*Breaking load*
Concrete	1	1	1	$4\frac{1}{2}$	5 tons.
"	2	$1\frac{1}{2}$	1	$4\frac{1}{2}$	$5\frac{1}{4}$ "
"	1	2	0	$4\frac{1}{2}$	$5\frac{1}{2}$ "

so that the concrete made of lime and sand, *without Soorkhee*, gives the best result.

(*f*). These are the only three *arches* I have made, but I have made a lot of concrete blocks in other different proportions, and the block made of lime and sand and stone is, I think, decidedly the best

* This was pounded sandstone. See after.—C C

of the lot. It rams much the best, and is now as hard as the hardest conglomerate in the district. But if soorkhee in the concrete seems to prevent the *hardening*, it seems to give a certain amount of *tenacity* which the sand does not give The arches built with soorkhee have given very slowly, and seemed to *tear*, that built of sand alone gave at once, without giving a sign, and regularly snapped like a steel bar, on that account, I think the best proportion would be to put in a little Soorkhee, say —

	Lime.	*Sand*	*Soorkhee*	*Stones*
(P)	1	$1\frac{1}{2}$	$\frac{1}{2}$	$4\frac{1}{2}$

A block made in this proportion is excellent, but is not yet sufficiently dry to compare fairly with the others

I think the ribs would have stood a great deal more, (1) if the backing had been built up, (2) if they had had a month or two more to harden.

Some of the blocks I have made are now over three months old, and some over four months old, but none of them have reached anything like what may be considered their maximum strength, they get harder and harder every day

I have commenced the centering for the Durroon bridge, which I intend to make of the ingredients shown at (P), 48 feet span, and 12 feet rise.

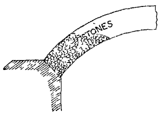
As to a rolling load and its effects, as far as I can make out, a 2-ton truck run up and down over the arch on rails did not seem to do the least damage, or to injure the arch in any way.

Taking the lowest breaking load at 5 tons at centre, this is equivalent to 10 tons distributed, and the width of the rib is 1 foot 6 inches Hence, working this out for an ordinary road culvert, 8 feet span and 12 feet width of roadway, it appears that the arch would not give till it was loaded with 1,863 lbs per square foot of roadway, or quite* nine times more than would in practice ever come on it On the strength of this, I consider it perfectly safe to make all my culverts up to 10 feet span of concrete, and am doing so everywhere.

We have had no great heat as yet, but cold frosty weather, and I cannot therefore say what the effect of great heat might be as to expansion, &c. One thing I noticed which may be useful and that

* See after, for an experiment giving even better results —G G

that very heavy rain injures the concrete very much, and makes its ·ack I would therefore, always protect the concrete arches from .in. If cracks *do* appear in a concrete arch, I think it would be a ɔod plan to run grouting into the crack, when the centering is re-.oved, the cracks close, and the grouting acts as a cement Another ɔint may be of some use I think all concrete arches should be ellip-cal, and not segmental, for this reason, that in a segmental arch, the ;ones work down from the ramming into the corner formed be-ween the arch and the slope of the abutting block, as shown below,



and the mortar of the concrete works up, so on removing the centre, the heel of the arch is composed of loose stone, which looks bad, and *is* bad, no amount of care could prevent this in a segmental arch, particularly if the rise was at all large In an ellip-tic arch, being flat at springing, here is no tendency to this collection of loose stones, and the heel of he arch is as well rammed, and as homogeneous as the rest

I mean to make the Durroon elliptical, as I find that shape quite oes away with the difficulty, which is otherwise a serious one You rill remember that all my experiments are on concrete *one month* old, which of course is not anything like sufficient to determine what con-rete *one year* old would do.

I also think, *if sufficiently dry*, that concrete made of mortar, with-ut stone of any sort, would be in the long run the best and strongest, ›ut it would take much longer to set really

Since my last to you about concrete I have broken another con-rete arch made of **1** lime, 2 sand, $4\frac{1}{2}$ stones, the sand being pure *washed river sand*, I previously used pounded sandstone for sand. The result is astonishing, the breaking weight being over $7\frac{1}{2}$ tons, or ıalf as much again as any other combination I have been able to nake with Soorkhee or with pounded stone Here is a triumph for rou! This arch yielded gradually, and did not snap, and I can make this concrete for 8 or 9 rupees. The result is due, I think, to the sand itself being chiefly composed of granite particles.

It will be seen that Lieutenant Browne considers the result of these experiments so satisfactory, that he intends to use concrete arches in all culverts up to 10 feet span, and he is also constructing a 40 feet arch in this material An account of a concrete bridge on the Metropolitan Railway, will be found in "*The Builder*" for 1868, pages 726 and 948 It has a span of 75 feet, with a rise of only $7\frac{1}{2}$ feet the width is 12 feet, and the depth at crown $3\frac{1}{2}$ feet. The materials used were six parts of gravel to one of *Portland Cement*, and it has successfully borne a test of 170 tons distributed equally over it, a train of seven trucks weighing 50 tons being run over it at the same time. Under these heavy weights there was practically no deflection.

In the Kangra Valley, ordinary arch-work costs from Rs. 20 to Rs. 40, exclusive of centering, whilst the cost of concrete is as follows for arches of *any* size —

Quantity	Description of Material	Rate			Amount	Total
		Rs			Rs	
18 cubic feet	Lime, @	20	0	0	3 60	
27 " "	Sand, @	0	8	0	·14	
9 " "	Soorkhee @	12	0	0	1 08	
81 " "	Broken stone @	2	8	0	2·03	6 85
135 " "	Labour in Ramming @	1	8	0	2 02	
	Sundries and contingencies @				·13	2 15
Total cost per 100 cubic feet, set in place,		.			. .	9 00

From the facts here collected, I think we are justified in assuming that, in the abstract, Concrete is a perfectly trustworthy material, and an economical one. I would submit further, that it is especially applicable to the Central Provinces, and that it ought to come largely into use there.

I.— It is cheaper than any other material of equal quality.

II —In many parts of the Province, there is no other material readily available. In some places, basalt of the hardest quality, and most costly to quarry and work, is alone to be found, and for many miles, even this cannot be procured in any reasonable quantity, and nothing but a

soft trap is available. Bricks, again, cannot be made of a durable quality from the "regur" and other soils ordinarily found, even when clay is procurable, it is so often charged with coarse sand, almost always calcareous, and other impurities, that brick manufacture is costly. On the other hand, a sufficiency of stone fit for for breaking can always be found, sand or gravel is plentiful, and the small quantity of Soorkhee and lime required will always bear the cost of carriage.

III —Skilled labour is scarce in these Provinces Masons can always command their own price, and a large number cannot easily be got together Not only are rates enhanced thereby, but only a few bridges can be put in hand at once, and work is thus delayed Now, any cooly can ram down concrete, and twenty culverts can go on where only two or three are in progress at present, so that Concrete not only saves money, *but it also saves time.*

IV —The main objection generally urged to the use of the material, is its expansion and contraction as the temperature varies This has been noticed only, I believe, in thin walls of great length and height, and (if I remember right) principally where cement was used Whether it would be found equally great with lime, especially when used in thick low abutments or in arches (which are free to expand), I very strongly doubt Even in the Punjab and at Delhi, with their marked extremes of variation (both daily and annual), no evil effects have occurred, nor could I ever find any signs of expansion fractures in the old roofs, and in the equable, steady climate of these Provinces, there seems no ground whatever for fear on this point.

V —Lieutenant Browne brings forward one objection—its liability to damage from rain, and therefore also from running water. I understand him to refer to the material before it has fairly set, but if not, I think this objection may be easily overcome by using a more tenacious compound in abutments and piers, and giving it a hard skin of plaster which, if made of the best stone lime, will prove an ample protection.

There is one point which should not be lost sight of. Close supervision is required to see that the proper materials are used, and that they are mixed in the right proportion But the same may be said of rubble or brick masonry. No engineer can be sure of the work in a bridge, unless he has seen every course laid before his very eyes, and

but too many of our culverts and bridges are mere shams—fair, externally to the eye, but within, mere bats and lime rubbish

I would urge, then, that this material should have a fair trial on a sufficiently large scale to test its value, its use being extended should it prove successful. The crying want of these territories is roads and bridges, and anything which will tend to reduce their cost and to expedite their construction, is a boon to the Province, and deserving therefore of every encouragement.

C C.

CAMP, SOHAGPOOR,
12th April 1869.

No. CCLI

HOFFMANN'S BRICK KILNS.

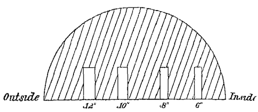
2nd Paper.

Instructions for setting the bricks and working Hoffmann's Patent Kilns. BY HERMANN WEDEKIND.

As soon as the construction of the kiln is completed, a number of fires are lighted in front of all flues leading to the chimney, as well as in various parts of the burning chamber, for several days, to drive off partially the moisture contained in the brick-work and floor. After this has been done, the next operation is setting or placing the bricks in the kiln ready for burning. The setting is done in the usual way as adopted in the ordinary kilns, with the exception that special care is required to form, immediately under each of the feeding holes in the arch of burning chamber, Fig 4, vertical pits from crown of arch right down to the floor to allow of a passage for the fuel inserted from above to fall right down on the floor Each of these fire-holes should be formed about 12 inches wide down to within six courses from the floor, where they should be increased to 18 inches square, for the reception and combustion of the fuel Besides in this kiln being four circular rows of fire-holes, and consequently four circular flues as shown in Figs 1, 2, 3a, 3b are to be formed along the floor, connecting one fire-hole with the one in advance, as will be readily understood on reference to the annexed drawing.

These flues form the passage for the flame to travel along the kiln; they

are made four courses high as shown in Fig 6, or bettre *Fig* 4, and are covered by the fifth course of bricks. In case the bricks are placed very damp in the kiln, it is well to raise the height of these flues a few courses to allow the steam sufficient room to escape. If the kiln is in full operation, it is well to make the inside flue narrowest, say 6 inches, and increase the width and height of the other central flues, as shown in sketch in margin, so that the



outside canal, being the widest, say 12 inches, and highest, say 24 inches to 30 inches, will draw the fire more to the outside of the kiln; as naturally, the draught has a tendency to pass along the shortest way at the innerside of firing-chamber, and thus some difficulty may arise to keep the fire proceeding with the same rapidity along the outside flue Figs. 1, 2, 3*a* & 3*b* illustrate how the courses of bricks are placed alternately one upon the other

For the lowest course along the floor it is advisable to take, for the first time of burning, round *burnt* bricks instead of green bricks, as the steam from the floor may soften the bricks placed immediately above it, which being unable to carry the weight of the whole bulk of bricks, would give way, and at once stop up the draught along the floor and cause delay and annoyance. This first course, as illustrated in Fig. 1. is placed rather open, leaving one inch space between each brick at an angle from the inside to the outside wall. The second course is shown in Fig 2, and the bricks are placed in the direction of the circular flue, on which again a skintle is placed, Fig. 3*a*, upon which again the bricks are set as in Fig. 1, then Fig. 3*b* shows the fifth course covering up the central flues. The next courses are again set alternately as explained in Fig. 1. and Fig. 2 The direction of every alternate course should be changed, while in one course, the length of the brick is set in parallel lines with the walls of the kiln, and taking the same onward line of draught, the next course above it should be at an angle from the inside to the outside wall, Figs. 1 and 2. Thus the compartment is filled right up to the crown of arch.

In setting, the workman commences at one end of the chamber where the large intercepting damper is placed, and continues so until he has five chambers filled without interruption. In the meantime, the doorways are built up with burnt-bricks, and made quite air tight by filling in sand between the bricks as illustrated in Fig 6 The men having filled chambers 1, 2, 3, 4, 5, Fig 10, the large intercepting damper is inserted through the door-way of compartment 6, and placed in front and across the chamber 5. This damper, as shown in Fig 5, consists of three parts built up and sliding in each other A special plan will explain this damper very clear, and further reference will be made to it hereafter. It is of great importance to place this damper in such a position that it forms an absolute air-tight division, as no air should be allowed to enter at any place, nor the heat escape. The same care is to be taken with the door-ways, which should be daily inspected several times.

In the meantime, while this is done, the chambers 7, 8, 9, 10 and 11 are filled with green bricks, as has been done with 1 to 5 inclusive, and a second intercepting damper, introduced through the doorway 12, is placed across and in front of chamber 11, Fig. 10, made air-tight as well as all the doorways leading to compartments 7, 8, 9, 10, 11. It may be here proper to observe that it is desirable to fill the kiln for the first time of burning at least, with bricks as dry as obtainable, as the new construction contains so much moisture, which is to be got rid of gradually, and excess of steam from bricks and building may injure the bricks to be burnt materially.

Lighting.—In chamber No. 12, in front of chamber No. 1 (Fig. 10). as well as in chamber No. 6 in front of chamber, No 7, temporary walls are to be built across the section of burning chamber, as explained in detail in Fig. 8, provided with four common kiln fires, Figs 8 and Fig 9, corresponding with the four central flues formed in the setting of the bricks along the floor. The valves in the smoke chamber Nos. 5, 4, 3 and 11, 10, 9 are to be opened entirely, while all others remain closed, bedded air-tight in sand. Fires may now be lighted in the two walls respectively, or in the eight permanent fire-places between chambers 12 and 1 and 6 and 7. These fires are kept *very low* for 48 hours at least, after which time they may be *gradually raised* for another 48 hours, until after about five days, the fires must be kept up to their *full intensity*. Of course all the caps covering the feed-pipes in the arch are to be kept

quite closed and bedded air-tight in sand. The first sign of the fire taking effect is a volume of steam escaping the chimney. If too much steam is created, which can easily be ascertained by lifting a few caps, out of which the steam will evolve in large dense masses, such caps may be kept open for awhile, as this is a sign that the chimney is not able to draw off the volume of steam as rapidly as it is created through the effect of the fire.

If *too much* steam is confined, the bricks become soft, and in many cases, the lower courses not being able to carry the weight of the bricks above them, they give way, and thus interrupt the draught along the floor, while many bricks will be spoiled and unfit for use In this way the fire is kept up from the temporary walls, until the bricks in the compartments near the intercepting dampers of chamber 5 and 11 are pretty well dry, which may be ascertained from the quantity of steam escaping by the chimney, which should be very little for about five or six days, making in all about 10 or 11 days. Now the fires in the temporary wall between chambers 7 and 6 are extinguished, chamber 6, which has been empty, is filled with green bricks as dry as they are obtainable with the least possible delay, as soon as men are able to set, after having removed the temporary wall

The chamber 6 thus being filled, the damper separating compartment 5 from 6 is removed, the door-way of chamber 6 built up and made air-tight, the valves 3, 4 and 5 are closed carefully, not to allow any air to escape, nor to enter the kiln, while the valves 9, 10, 11 remain wide open, and the fire at the temporary wall 12 is increased to the greatest possible intensity. As soon as the chamber 1 is *hot enough*, the burning is assisted by throwing in fuel through the feed-holes near the temporary wall, if the fuel reaching the floor *ignites*, continue to do so through the first and second row of feed-holes and fires from the temporary wall as well as from above As the heat proceeds, the firing likewise proceeds at the same rate from above, and as soon as the fire reaches chamber 3, the fire in the temporary wall is decreased, and a little air is allowed to enter at the permanent wall by taking a few bricks out of it from under the arch.

As soon as the fire has advanced as far as chamber 4, the valve of chamber 9 may be closed, the fires in the temporary walls put out, the *fire-places filled up*, a larger opening formed in the upper part of the tem-

porary wall for access of air; and when the fire has reached chamber 7, the temporary wall at 1 may be quite removed, allowing the air entering through the door-way of 12 free access to cool the burnt-bricks in 1. As soon as the fire has advanced as far as 8, chamber 1 is emptied of burnt-bricks, chamber 12 filled with green bricks, and the intercepting damper removed from 12 to 1. The valve 10 is closed and 12 opened, after having the door-way of 12 built up air-tight as illustrated in Fig. 6. Now the kiln is in working order, and the fire will advance every day along one chamber, therefore one chamber is *daily* to be drawn, and one chamber to be filled, the large intercepting damper being removed and advanced. One valve is closed every day, and one in advance is opened, thus it is found expedient to have generally two valves open. If however, the kiln is very dry, and the bricks placed in the kilns quite air-dry, it will often be found sufficient to open only one valve at the time. *It is not necessary* to leave *the whole chamber* (6) empty, as the temporary wall may just as well be built as shown in dotted lines nearer the damper Fig. 10, and the little place left may sooner be filled or left *half filled*, that is, the bottom part to guide the flame, while the top part may remain empty, which would permit a shorter interruption of the working of the kiln. Of course, while the temporary wall is drawn and chamber (6) set, the dampers or valves 10 and 11 should be almost closed, so as not to draw in more cooling air than is necessary to enable the workmen to operate on chamber (6).

The fire on the kiln should always extend over at least *ten rows of feed-holes,* and as soon as the row in advance is ready to ignite the fuel at the bottom, one row in the rear is left off firing, and thus it regulates itself. It is very important to feed at *regular intervals,* to arrive at the utmost saving in fuel and regularity in burning. Presuming there are *nine* rows of holes to be fired, each hole should be fed at intervals of 15 minutes.—

1	2	3	4	5	6	7	8	9
O	O	O	O	O	O	O	O	O
O	O	O	O	O	O	O	O	O
O	O	O	O	O	O	O	O	O
O	O	O	O	O	O	O	O	O

At the full hour, row Nos 1, 4, 7 is to be supplied with fuel,
Five minutes past the hour, Nos. 2, 5, 8,
Ten ,, ,, ,, ,, 3, 6, 9,
Fifteen ,, ,, ,, again ,, 1, 8, 7,

and so soon. If, sometimes, it should be found some feed-holes require

no supply, the fuel not being sufficiently consumed, they may be left out, but this will scarcely happen if the firing is attended to regularly.

It may be well to describe the working of the kiln in a few words to understand and appreciate the principle thoroughly. The cold air can only enter the annular chamber through two door-ways, *viz.*, one for drawing, and for one removing, the bricks. As it proceeds onwards in its line of draught to the chimney, it enters the first of the cooling chambers by which it is warmed. As it percolates amongst the bricks in the second chamber, its temperature is considerably raised, through the third, it attains a high burning heat; and in the fourth, it reaches a glowing heat almost as high as the burning-bricks. With its temperature thus raised, it now passes the two burning compartments supplied with fuel, and mixing with the hot gases from the fire, perfect combustion in close contact with the goods is the result. Passing on from the burning chambers, it passes the 7th, in which the bricks are absorbing the waste heat, and they are brought to a low red heat before any fuel is supplied; the 8th chamber is warmed to a good heat, the 9th is dry and warm, while the 10th is steaming and drying off, while the moist gases and products of combus-

[illegible]

screwed down in the sand, to see that the intercepting damper does not allow any air, to examine all closed valves, that they are bedded well in sand, and frequently to inspect the built-up door-ways, that they may prevent any cold air from entering the kiln. The attendant should frequently go into the smoke chamber and inspect the valves to see whether they close air-tight in a bed of sand, which he can soon learn from a whistling noise, or by moving a candle round the seat. For this purpose, a *manhole* should be provided to allow access to the valve chamber.

In *using coal* for fuel, the fireman has a small hook and scoop, the one for handling the feed-cap, and the other for supplying coal. He should not keep the cap longer off the feed-pipe than is just required

o supply the coal with his other hand, and he should insert a very ittle at the time, perhaps $\frac{1}{2}$ pounds, just enough to burn away durng the 15 minutes' rest. If too much fuel is supplied, the central flues vill be stopped up through the accumulation of incandescent fuel, and he result would be an increase of heat at this particular place, meltng the bricks, partly cutting of the draught, and thus interrupting the egular working and progress of fire, besides causing a waste of bricks. If equired to retard or even stop the progress of the fire, the valves in the moke-chamber must be *almost* closed, only leaving one valve about one nch open to prevent a back draught The fireman's duty is therefore to eed at regular intervals, and keep the kiln everywhere air-tight so that o cold air is allowed to enter except through the two open door-ways; nd he will have no difficulty in burning sound bricks rapidly

Plate XL explains the construction of the intercepting damper in etail The damper consists of three iron-plates A, B, C, one placed bove the other; against the drop-arch, D, is a shoe in which the several ieces slide, while the damper is being removed. For removing the lamper, little crabs are applied to raise the upper plates, while the lower nes are withdrawn.

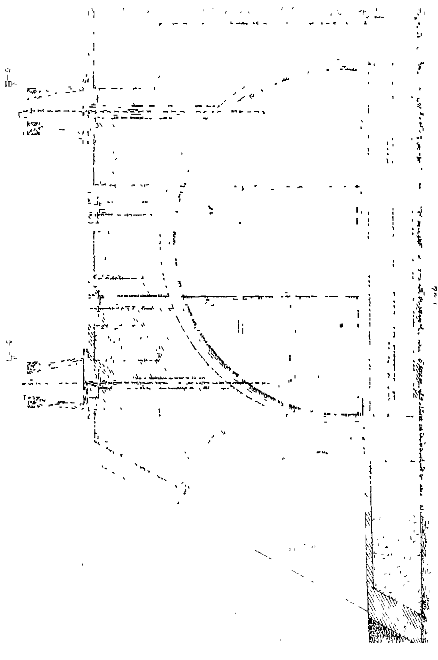
The iron-work for each kiln of 14 chambers consists of:—

280 sets of feed-pipes and caps.
14 30-inch valves.
2 large intercepting dampers.
4 sets of feed-pipes, and 1 valve of 30-inch diameter are sent as reserve pieces.

LONDON, 11*th May* 1869. H. W.

HOFFMAN'S BRICK KILNS.

(Intercepting Damper)



No CCLII

ON PERSPECTIVE.

The Theory and Practice of Perspective, in two Rules. BY CAPT. A. M. BRANDRETH, R.E.

WITHOUT some general knowledge of perspective, the artist will surely make unsightly mistakes in any drawing from nature, and as many amateurs are, I believe, frightened from learning the rules by thinking them difficult, or that it is necessary to know Mathematics to understand them, I am induced to write this paper, and to make it simpler, let me address my reader direct.

If you take a pane of glass, the size of your sketch book, and hold it upright before you, so as to see *the view* that you wish to draw through it, *the picture* you wish to make will appear as if drawn on the glass By moving the glass further away from your eye you will take into your picture fewer objects, which will be larger than before, and *vice versâ*, by bringing the glass nearer you, you will take in a larger view, but on a smaller scale It is this distance of the glass from your eye which is the first thing to be decided on, and this is called Definition I.

Definition I.—The distance of the picture, which will in future be written *d* of *p* for shortness sake

Strictly speaking this distance should be about the same as the breadth of your paper, as this gives about the opening your eye can take in at once and you should arrange your picture in the glass by moving yourself towards or away from the view but as this cannot always be done as many views can only be seen from certain spots, the arrangement is often made by altering the *d* of *p*.

Now as you sit with the glass held up before you, at the correct distance, the position of your eye is called

Definition II.—The point of station, which I shall in future call S only

Next, the direction in which you are looking, or a horizontal line straight to your front is called

Definition III.—The line of sight, to be called *l* of *s* in future, and the point in which that cuts the glass is called

Definition IV.—The point of sight, to be called P in future.

A horizontal plane must be imagined to pass through your eye, and therefore through the line of sight and P, and to cut the glass in a straight line right across it, which is called

Definition V.—The horizontal line, to be written H line in future, to distinguish it from any other horizontal line

The plane of your glass which is supposed to extend to any distance up and down and sideways is called

Definition VI.—The plane of the picture, to be written *p* of *p* in future

Vanishing points, and *points of measurement*, are the only other terms used, and they will be explained presently

Now every object you see has to be represented in your picture by lines We may leave curved and crooked ones out of the question for the present, as their treatment will be explained hereafter. All the straight lines in the view are divisible into two classes I Those parallel to the *p* of *p* and, II. Those not parallel to it, whether they are oblique or perpendicular to it.

First, then, as regards lines parallel to the *p* of *p* Now clearly understand what this comprehends; if you are standing straight opposite to the side of a carriage, to draw it, not only those wheel spokes which may be horizontal are parallel to *p* of *p* but every spoke in every wheel.

Now turn to Sheet I. which represents any one sketching, as you would see him if you were standing to one side of him, and Sheet I*a* as he would appear if you could get a birds-eye view of him from right above line. Let S be his eye, M N the *p* of *p*, AB *any* line in the view parallel to *p* of *p*,—Say for example the corner of a house, the ground line of the same, or a line across its face from corner to corner, *any* line in fact, that lies in a plane parallel to *p* of *p* might have been taken, but in this picture, AB is an upright line. Then let SD be *l* of *s*, P the point in which it cuts the paper, and D a point in it the same distance

from the *p* of *p*, as is AB, both measured square to the *p* of *p*. *See* sheet I*a*.

Then SP is the *d* of *p*, and SD is the distance of the object AB, which is always measured this way, not direct.

Then for Rule I., *ab*, that is the representation of *any* line parallel to *p* of *p*, is to its real length AB, as SP or *d* of *p* is to SD, or distance of object or line. This is, I think, pretty plain from the figure, but for proof *ab* : AB :: *Sa* : SA or as SP : SD. Thus it follows that if EF be any other line equal and parallel to AB, and at the same distance from the eye, then also is *ef* : EF :: SP : SD therefore *ef* is equal to *ab*. This is, to be sure, a piece of geometry, but such a simple one that there can be no difficulty in understanding it. To take a common example, suppose you were drawing a row of equal houses, standing straight opposite them, they will all be the same height and breadth in the picture, so will their doors and windows, and any equal diagonal lines, such as those we may imagine drawn from corner to corner of the windows, will, in your picture, as in nature, be equal and parallel, because they are all parallel to *p* of *p*. The rule is general and may therefore be thus laid down.

Rule I.—Any natural line parallel to the plane of the picture, will be drawn in the picture parallel to itself, and bearing the same proportion to its natural length, that the distance of the picture does to the distance of the natural line from the eye.

This makes a very simple affair of all lines parallel to *p* of *p*, so let us go on to the next class, or lines not parallel to *p* of *p*. Now suppose yourself, sketch book or glass in hand, sitting on a vast plain. It is no matter whether level or not, so that it is one even surface. Then suppose a friend to stand in front of you touching your eye with his fore finger; now let him walk away backwards in any direction he likes, so that he keeps in one direction; his feet will make lines, and similarly, for example's sake, all points of him, the top of his head, his hands, and the point of his fore finger, if he held his arm stiff as it was when touching your eye, may be supposed to make straight visible lines which you wish to draw. If he goes away far enough, your friend will become smaller and smaller, and at last vanish in a point, and all the lines he has made will vanish in the same point. Therefore, if you can find the point in which one of them vanished, you will have the vanishing point of them all. But the line traced by his finger from your eye, has been a point all the time, since it

is a straight line pointing direct from, or at, your eye. This is *the* point therefore, and as the same would be true whatever size your friend was, that is to say, however many points he had about him to describe parallel straight lines, we have, Rule II.

Rule II.—All natural lines in the view which are parallel to one another, and not parallel to p *of* p *vanish in, or must be drawn in the picture tending to a point, in which a line parallel to them from the artist's eye, or S, cuts the plane of the picture.*

Or perhaps it will stand better.

Any natural line in the view not parallel to p *of* p *vanishes in, or must be drawn in the picture tending to, a point where a line parallel to it from S, cuts the* p *of* p, *and any other lines parallel to these will also vanish in the same point*

This is very simple and also general, you will see that, in the same picture, there may be dozens of vanishing points, as many, in fact, as there are lines to be drawn which make angles with each other, or as you can imagine friends walking in different directions, some up hill, some down, some on the level, some straight away, some across you right to left, and some *vice versâ*. But any number of lines that are parallel, or say, each set of parallel lines, will all go to their own one of these points, no matter where they are in the picture, as any one of your friends may be so big that his right foot may start from one edge of the glass and his left from the other Also, it is not necessary that the V.P (or vanishing point) of a line should be in the limited space of your sheet of paper, it will often be outside it, but always in the same plane *i e*, the *p* of *p*. For the generality of the rule, it includes Rule I, for the line from S parallel to any line which is parallel to *p* of *p*, will evidently never meet the *p* of *p*, and therefore these lines have no V.P. *i. e.*, must be drawn parallel to the *p* of *p*

I have taken the general case first, and supposed our friend to walk in any direction and up or down hill, or on the level, so long as he sticks to one direction, so as to make his lines straight, and the rule is one for all these cases, but, in most cases in practice, the lines we wish to draw are horizontal, and this narrows the application, *not the rule*, to the fact that every V.P. will be in the H. line of the picture, as, of course, if your friend walks on a horizontal plane, his finger at your eye would be in *the* H. plane to start with, and will evidently keep in it. Also, further, if he

walks straight away from you, so that his finger traces the *l* of *s*, the V.P. will be P. Thus with horizontal lines parallel to the *l* of *s*, the V P. is P, and every oblique horizontal line has its V P. in the H line.

Take an example If you stand in a street and look along it, straight along the street, P is the V P of all the horizontal lines of the houses. If you look so as to see one side only, or anyway oblique to the direction of the street, the V P will not be P, but still it will be a point in H line: where a line from your eye parallel to the street would cut the *p* of *p*.

These two rules comprise the whole theory of perspective Let me now try to show how to put the theory into practice Turn to Sheet II, which shows the position of three articles on a table that you wish to draw in perspective, viz a short octagonal pillar, a box, and a slice of cake Their dimensions and positions are given in inches, and you must understand that this is merely a ground plan to show you what size &c, the things you wish to draw are Now you must sit down at S, 40 inches from the edge of the table, and to make the objects more like buildings, which we should naturally be drawing, but which are inconvenient for examples, sit on a low chair so that your eye comes only 12 inches above the table. Then look straight along line of sight S.Z and in this line stick up a wire 12 inches high out of the table, the top of this will represent your point of sight, P, as your eye is 12 inches above table

Now this is, to all intents and purposes, as if you were sketching a Cathedral; you would there take up your position, and spot some mark in the building opposite your eye for P, and imagine your H. line running through it, from which to take all your measurements, just as you are going to do now

Now turn to Sheet III. This is your picture, and as it is rather confusing to follow the separate steps on a complete picture, I advise you to take a clean sheet and draw the lines yourself step by step First then, draw the H line QR, and mark P on it wherever you like your picture will come in with reference to this line and point all correct wherever you put them on the paper Now see on Sheet II, the lines which are parallel to the *p* of *p* are the edge of the table, and any in the sides AB, IT, IJ, LK and MN all the others are not parallel to the *p* of *p*

Now the first thing to decide on is the distance of the picture, or the size we shall draw the objects. let us say the *d* of *p* is 8 inches, I have of course arranged the dimensions here to save fractions; they would not

usually come so neat in practice, I have also been obliged to draw the picture half the size given below, or as it would appear if d of p was 4 inches, so as to make it a reasonable size to print, but you will find it best to take the dimensions given and make the picture larger

Now to begin with, let us draw the edge of the table, its actual distance from S is 40 inches while d of p is 8 inches. Therefore, any object there will be by Rule I. $\frac{8}{40}$ or $\frac{1}{5}$ of its real size, and as the edge is 12 inches below horizontal plane, it will appear on picture $\frac{1}{5}$ of 12 inches below the H. line QR. Thus, measure $2\frac{2}{5}$ inches below QR, and as edge of table is parallel to p of p, draw a line through this point parallel to H line, which will represent the top edge of table. Then, suppose it is $1\frac{1}{4}$ inch thick, it will here appear $\frac{1}{5}$ of that or $\frac{1}{4}$ inch, draw another line $\frac{1}{4}$ inch under the first and there is the edge of the table

Now let us try the side IJ of the box, it is distant 64 inches from S, and as d of p is 8 inches, will therefore appear $\frac{1}{8}$ its real size The distance of J from l of s is 8 inches, and therefore will be 1 inch in your picture. Draw an upright line at this distance from P Now the box being 12 inches high, its top will be on the H line, and its bottom $\frac{1}{8}$ of 12 inches below that line, or $1\frac{1}{2}$ inch; this gives you pJ, IJ is 16 inches, and therefore I will be 2 inches distant from J in your picture, iI will be equal and parallel to pJ, and thus you have the whole side of the box

Now to impress this, put in the side AB of the pillar AB is 48 inches distant from S, and will therefore be $\frac{1}{6}$ of its real size The pillar is half above, and half below, H line The distance of B from l of s is 27 inches, and will therefore be $4\frac{1}{2}$ inches on the picture; and A ab B will grow up just as the side of the box did In just the same way, you can put in side MN of the cake, and this finishes all lines parallel to p of p

Now for the other sides which are *not* parallel to p of p. First, let us take BC, Sheet II., as this is a general case i e may be taken as a representative line for any one you can possibly draw. Then, by Rule II, to find the vanishing point of BC and all lines parallel to it, we have only to draw, from your eye, a line parallel to BC, to meet p of p in some point, which will be the V.P. required; now the question is, how to do this? It may be done on the paper of the drawing itself. Fix* your drawing upright, and take a stiff sheet of paper 8 inches deep and lay it on your drawing with its upper edge along QR. Then mark a point on its lower

* This must be yours not mine as yours has no S or line S V. on it yet

edge immediately under P, call this S and turn the stiff sheet up, still keeping its edge along QR, till it stands out horizontally, then, if you place your eye at its edge at S, you will be in the right position with regard to *p* of *p*, and the stiff sheet will represent *the horizontal plane* Now as BC, in sheet II, is on a horizontal plane, a line can at once be drawn parallel to it on this stiff sheet, which will meet the *p* of *p* in the H line in some point which we call V and which will be the V P required *i. e* of the line BC and all parallel to it. But if you lay your stiff sheet flat on your drawing, still keeping its edge along QR, you will find you might as well have drawn SV on the drawing, without any stiff sheet, only taking care that the angle PSV is equal to that that BC makes with SZ in Sheet II. Similarly, if on the stiff sheet, you had drawn SV parallel to MO, you will find it will give you the same point *i. e.* the V P of MO and all parallel lines, as if you drew it on Sheet III or the drawing, and so for any horizontal line The plan, therefore, pursued is to take, on the drawing, PS perpendicular to QR, and equal to the distance of the picture (or in this case 8 inches) and draw SV parallel to BC, that is, making same angle with PS that BC does with PS on Sheet II Thus, then, the V.P. of BC and lines parallel to it, is in V, so we draw BV, *b*V.

The question now is how are we to find the point C? or how much to cut off BV and *b*V to represent BC, and *bc*? There is no new rule or principle required for this, only a little application of Rule I or II. To apply Rule I, find how far C will appear below the H line in the picture, considering its distance from S, and the point in BV, at that distance below QR, must be C, but it is generally done by Rule II. thus :—Lay off on Sheet II BT equal to BC, and parallel to *p* of *p*, and put it on your picture just as you did AB. Then find the V P, of real line TC, which call X, and from T, on picture, draw TX cutting BV in a point which is evidently the position of C, and draw C*c* upright to meet *b*V This is the plan usually adopted, and is, perhaps, worth a separate example, which I have therefore given in Sheet IV.

Let AB be any real line, *a* the position of A in the picture, of which P and S and line QR are as usual. Draw SV parallel to AB Then V is V.P., of line AB, and AB will be drawn in the picture in direction *a*V It is required to find the position of B, or to cut off from *a*V, a portion which shall correctly represent AB Suppose the real line AE drawn parallel to the *p* of *p*, and equal to AB, and a line CBD drawn. Now if

we can put these two lines AC and CD correctly into the picture, the point in which the representation of CD cuts aV, will evidently be the proper position of B in the picture. By Rule I, put in ac, the correct representation of AC Draw SX parallel to CD This gives X, the V P. of CD Draw CX cutting aV in b, which is the point required Now as the triangles ABC and VSX are evidently alike, since their several sides are parallel, VX is equal to VS as AB is equal to AC Thus the simplest plan of finding the point X is to take VX, along H line equal to VS. This point X is called *a point of measurement*

Now to return to our drawing, Sheet III, put in CD, in just the same way as BC. Since CD is parallel to l of s, its V P is P. Draw CP Now to cut off CD from this, lay down CV on Sheet II, parallel to p of p, and equal to CD Now C being 52 inches from S, and p of p, 8 inches, CV which is 6 inches, will appear a trifle less than 1 inch; draw this in your picture Then take PS, since P is V P of CD, and lay off PW along H. line, equal PS. Join VW, cutting CP in D, which is the point required Then draw Dd to meet cP.

Now we only require to draw the side AH to complete the pillar. The V P. of AH will be W, since SW is parallel to AH Join AW. Now you may cut off AH just as you did before, but you see at once that H is the same distance from p of p as C, and, therefore, HC is a line parallel to p of p; so in picture, draw from C a line parallel to QR, cutting AW in H the required point Draw aW and Hh as before

Thus, it is not always necessary to use the plan mentioned in page 7 to cut off a required portion from a line; it can often be done otherwise according to the points we have down on our picture. Thus, for instance, to find position of centre of base of pillar, you know it is in DH; join DH on your picture; but it is also in a line from centre of AB parallel to line of sight, the V.P. of which is P. So, from the centre of AB in your picture, draw a line to P, cutting HD in a point which will be the centre of pillar. I have omitted those lines to save confusion; now you can yourself put in the sides JK and MO.

To draw a curve, you have only to find the position of any convenient number of points in the curve, and draw the curved line through them by hand. The more points you fix, the more correctly your curve will be represented. Thus HABCD might all be points in a circle. Work out any other example for yourself and you will soon get into the way

of it You will find Rules I. and II. answer every case you can invent

Let us now try a case where the lines are not horizontal; such, for example, as the lid of a box half open—the box itself being placed oblique to p of p, to make a general case of it

See Sheet No V. We will only take the line AB, as this will show all the variety from the previous cases. Let *ac* be the correct position of AC in the picture, V its V P and SP and QR as usual. If AB were any unconnected sloping line, the first thing to do is, by previous plans, to draw AC like the edge of the box horizontal, and directly under AB and put *ac* first on the picture, so this is a general case of *any* line AB.

Now, if we think of the pane of glass again, and imagine the horizontal line SV actually drawn to it, and another SW vertically above it, but sloping upwards so as to be parallel to AB, then W will be the V.P. of AB and all lines parallel to it, by Rule II. We have, therefore, only to find the distance VW, and on our paper mark W at that distance above V Now it is just the same, as far as the length of VW is concerned, whether we imagine the triangle SVW drawn in the air to the glass, or draw them on the paper. Make then the triangle SVX where VX is perpendicular to SV, and the angle VSX equal BAC Then VX is the required distance of W above V, and W will be the V.P of AB and all lines parallel to it. Draw then *a*W

Now to cut off *ab*, equal to AB, we must employ some dodge. The simplest perhaps is to draw real BD, so that D is immediately under B. Put AD on picture, as *ad*, and draw an upright line from *d* to cut *a*W, which it will evidently do in the required point *b* Sometimes another plan will be easier, according to the points you have down on your picture

What I wish to impress is that there is nothing new after Rules I. and II, writers on perspective are so apt to give rules for putting all sorts of objects in perspective, such as for a square, a cube, an arch, a church &c., multiplying examples without explaining the principles. I have tried to follow the opposite line, and hope that you will multiply the examples according to your need A simple example would be to change your position to some other point and height in Sheet II, say to X, 2 feet above the table, and draw the same object. They will make quite a different picture from this point of sight.

You will see how the principles can be applied to the drawing of animals even, by considering them as if square between their prominent points, getting these points in by perspective, and rounding in the intermediate curves afterwards. Try a three-quarter face, and see how the direction of the cross lines, eye brows, mouth, &c., will vary according as you are above, on a level with, or below, the face.

There is, of course, seldom necessity to use the rules of perspective in this detailed measurement way in which its principles have of necessity been shown. In sketching, the proper size of the objects, or the application of Rule I, will always be guessed at, but Rule II, must be carefully attended to, or else mistakes which will catch any one's eye, will be sure to occur. In sketching any building, you have only to follow up two of its most conspicuous parallel lines, the eave and ridge perhaps, and see where they appear to meet, and then remember that all lines parallel to them will be drawn tending to that point.

Every building has two principal vanishing points; one for lines in its side, the other for those in its end, and these are the same for all buildings placed square with it. If, in the same picture, there is another building placed at an angle to these, it will have its own V.P; so remember this and that all these V.P's, being for horizontal lines, must be in the H. line of the picture, so that all horizontal lines above your eye seem to run down to the H line of your picture, as they recede, and those below, upwards to the same line, will save you much delay and trouble in sketching, and give your drawing a true look that it cannot have if these considerations are neglected.

Believing that nothing can be remembered that is not understood, I hope this little article may be useful, and that I may be excused for writing it, when I say that I have never seen anything of the sort printed before, the Treatises that I have seen being either mathematical demonstrations or rules without explanation.

A. M. B.

No CCLIII

IRRIGATION IN THE MADRAS PRESIDENCY.

Report by COL. J C. ANDERSON, R E., *Chief Engineer for Irrigation.*

Dated 11th December, 1868.

IN forwarding a summary of the reports from the Superintending Engineers of Divisions on the results of surveys and investigations lately carried out in connection with Irrigation Projects in this Presidency, as called for by the Government of India, I propose to furnish the Government with an account of the bearings of the projects which have been under inquiry, in connection with the present condition and the extension of irrigation in this Presidency

Ganjam.—To commence at the Northern boundary·—In Ganjam, Captain Beckley R E., has recently been employed in examining the capabilities of the district for extended irrigation, and has had his attention engaged in devising means for utilising the supply of the principal river in the district, the Rooshkolia (drainage area, 2,400 square miles); and a preliminary report has been submitted. The present condition of the irrigation in Ganjam is described as extremely defective. There are a great number of tanks, but, with two exceptions, they are of insignificant size, and though the rain-fall, even in the worst years, is believed to be sufficient for the wants of the district, if reservoirs were available to store even one month's supply, the loss of a portion of the crops is a common occurrence even in average years, and in bad years the whole crop is lost, and a famine is the result.

While the smaller tanks are powerless to save the cultivation under them, the large tanks are perfectly efficient. Of the two specified by Captain Beckley, one yields a revenue of Rs. 15,000, and no remissions

have ever been made, and the other, which yields upwards of Rs 10,000, furnished a plentiful supply of water to the lands under it when the failure of crops elsewhere was so complete as to occasion a famine. "The general condition of the district must, I think be pronounced unhappy, and such as to demand amelioration The prevailing custom of growing rice upon lands depending solely on the rains for irrigation must always be a source of anxiety to the people and to Government, and must produce famines periodically, perhaps the oftener now that high prices and other causes have given great impetus to the export grain trade the soil is rich and fertile, there is little barren or stony land—the hills rising abruptly from the plains the rain-fall is very large, though not excessive, and though variable, never appears to fail all parts have short easy access to the sea, but, notwithstanding all these advantages, Kurnool and much of the Bellary District evince signs of far greater prosperity than Ganjam. Doubtless much of the squalor and wretchedness observable around is due to the apathetic character of the Ooriahs, and one great argument in favor of large Public Works is that, through them, the people would be trained to labour, and their indolence gradually overcome"

Captain Beckley suggests the construction of a series of large reservoirs, but in preference to dealing with them singly, he proposes to form them in connection with channels from the principal streams in the district. He proposes to construct a dam across the Rooshkolia to the west of Aska, and above the junction of its principal tributary, the Mahanuddy; to lead the supply of the latter by a cross cut from a point above, the configuration of the country preventing his fixing his head works below the junction; and then to carry the combined supply from the two rivers by a cutting to the southward, between two ranges of hills, into the valley of the Shargaddah and Godahallow (two other feeders of the Rooshkolia). The plain country is then reached, and no obstacle would be experienced in carrying the channel onwards to the coast at Chetterpoor near Ganjam.

It is further proposed to make the channel navigable, and to open out the section from Injelly to Ganjam in the first instance. Captain Beckley appears to have formed a favorable opinion of the scheme, as regards its remunerative results and its effect in improving the condition of the country, but the investigation cannot as yet be considered to have advanced to such a stage as will allow of Government forming any conclusions re-

the Godavery Delta works, exclusive of the charges for general establishment, has amounted to the following sum.—

		RS
New Works,	... .	42,45,648
Repairs, ..	.. ..	34,17,029
Machinery,	.. ..	4,16,116
		80,78,793

A project for the formation of a considerable reservoir beyond the Delta limits has recently engaged the attention of the Superintending Engineer, Captain Ryves The site is at the village of Unnoomoolunka. Fifteen square miles of country have been surveyed, and forty miles of contour levels carried out, from which it would appear that about 465 million cubic yards of water would be obtained on the supposition that the fall of rain is only $22\frac{1}{2}$ inches The bund would be eighty feet high and one and a half miles long, and the cost would be about twenty lakhs. This project has not been worked out in detail, and it would be premature to express an opinion upon it; but it is desirable that the investigation should be continued, since, as Captain Ryves remarks, besides its value as a source of supply for irrigation, the reservoir would be of great service in reducing the volume of the Yerrakalva floods, which have now to be passed across the Delta, between embankments, and which in seasons of excessive rain-fall, *may* be productive of very serious injury to extensive tracts of irrigated lands

The construction of an anicut across the Godavery at Polaveram, about twenty miles above Rajahmundry, was advocated many years ago by Sir A Cotton (I write from memory, and may be mistaken, as I have been unable to trace a reference to this project in any of Sir A Cotton's reports in my possession), but the subsidiary channels would necessarily be of a more expensive character than those in the Delta, and although the project is likely at some future period to merit attention, it cannot be seriously thought of until the Delta system is fully completed.

Kistna—The Kistna Delta works are similar in character to those of the Godavery, but having been commenced five years later, they are not so far advanced. The general scheme for completing the whole of the works has already been submitted to Government, and sanction has been accorded to various projects, forming portions of the whole, which will occupy the establishment for a considerable period The detailed plans and estimates for the remainder of the works are in a backward state, and

at this moment are in abeyance, in consequence of the Superintending Engineer having expressed his inability to form a reliable estimate of the whole area of land which is likely to be brought within the influence of the channels eventually

The expenditure on the Kistna Delta works up to end of 1866-67 has been as follows, charges for general establishments not being included —

	RS
New Works,	27,35,196
Repairs,	11,05,832
Machinery,	1,47,489
	39,88,517

In the Kistna District, but beyond the Delta limits, a project has been under investigation for utilising the flood-water of the Moonyair, a considerable river (drainage area, 3,050 square miles), which passes through the Nizam's territories to within thirty miles of its junction with the Kistna The project will have to comprise the formation of tanks for the storage of flood-water, and in that respect it will be more expensive than the majority of irrigation works which have been carried out by our Government.

A project for the restoration of an old native tank at Dondapad, in the south-west corner of the district, has also been partially investigated, and Government allotted funds in 1867 for the prosecution of this work and of another of a similar kind, but the preparation of the plans and estimates was not sufficiently advanced to warrant the Superintending Engineer commencing the work during that year, and since then, the Officer who was employed on the investigation (Captain C J Smith, Royal Engineers), has been obliged to go home on medical certificate. The drainage area is of limited extent, thirty square miles, and no very important results are to be anticipated from the work

Both in the Gadavery and Kistna Districts, the irrigation works out of the Delta limits though numerous, are individually unimportant. The country is undulating, and in some places hilly, and the works cannot be embraced under one, or even under many, separate systems they must be treated in a great measure singly A great deal of cotton is grown in the south-west portion of the Kistna, the soil is also well adapted for dry cereal crops, especially for cholum or jowar The tanks, besides enabling the cultivators to raise a small quantity of rice, are also very valuable as

reservoirs of drinking water for the people and their cattle. The Kistna itself has no influence beyond the Delta, as the country rises rapidly away from it. It carries an enormous body of water to the sea even in the worst years, and it would be quite possible, if an anicut were constructed about thirty miles above Bezwada, to lead the water to a much higher level than can be commanded by the existing channels But such a project would be greatly more expensive than the Delta works, owing to the undulating and rocky character of the country, and it would be quite premature to take it up seriously, while the irrigation in the Delta is only half developed This project was recently recommended for investigation by the Acting Collector of the Kistna District, Mr Wilson, who is under the impression that the site he selected at Chintapully had not attracted the attention of the Engineers in the district, but it will be seen on reference to the original report* on the Kistna anicut, that the river was fully explored, and that the site in question was rejected on account of the difficulty of dealing with the floods, which there attain a height of fifty or sixty feet above summer level.

Nellore.—The Nellore District is traversed by one large river, the Pennair; drainage basin 20,000 square miles As far as Sungum on the north bank, and to near Nellore on the south, the country falls towards the river, but from these points towards the sea, a considerable alluvial tract extends from the north and south banks of the river respectively. From Nellore, on the south bank, the Pennair water has been distributed by means of an anicut and a complete system of channels to the whole of the land which can be commanded in that direction, which may be considered as a parallelogram twenty miles long and twelve wide

On the north bank, the tract within the command of the river is already very richly provided with tanks, to some of which flood water has hitherto been led by means of imperfect channels of native execution. It is now proposed to form head works at Sungum, thirty miles from the sea. to lead all the ordinary flood water available in the Pennair, after the lower Delta works are provided for, by a capacious channel, into the Kanigeri tank, already one of the largest in the country: to enlarge its capacity, and that of another tank adjacent to it, so as to allow of their holding together about 340 millions of

* Professional Papers, Madras Engineers, Vol. IV. p.p. 8, 9.

cubic yards, and to distribute the water from them not only to all the purely deltaic lands which are under command of them, but to a tract of country beyond. The area to be irrigated is computed at 80,000 acres. This project, which is estimated to cost between twenty and thirty lakhs of rupees, is now matured, and the preparation of the plans and estimate far advanced I have every reason to believe that the project, which has been drawn up by Mr R Smith, Executive Engineer, will commend itself to the favorable consideration of both the Local Government and the Government of India

The other rivers in Nellore, with the exception of the Soornamookhy, near the southern limit of the district, and the Gundulcumma, on the north, all rise in the Eastern Ghauts, which run nearly parallel to the sea, and at the distance from it of fifty or sixty miles. The floods brought down by them are of a spasmodic character; and as their supply is derived almost entirely from the north-east moonsoon, which is not only of short duration, but of very uncertain character, there is no field for any extensive irrigation systems, besides those above-noted, in this district, though doubtless a good deal may be done towards improving the flood channels leading to tanks, and the tanks, themselves, some of which are already very fine works

The examination of the Soornamookhy (drainage area, 1,174 square miles) will shortly be taken in hand. Improvements to the supply of various tanks under it have been contemplated for several years past, but, in consequence of the greater part of the land along the south bank being zemindary, and of the zemindar claiming certain rights with regard to the water-supply of the river, the local Officers have been deterred from taking up the subject, being hopeless either of coming to an amicable arrangement with the zemindar, or of being able to establish a right to any specific proportion of the water in favor of the Government ryots The longer any matter of this kind is left unsettled, the more difficult it is to arrive at any result, and I would, therefore, propose to have the river examined as soon as a Surveyor can be set free from the Sungum project The Gundulcumma (drainage area, 3,100 square miles) is a considerable river, but the supply from the most important part of its basin is already absorbed by the great Cummum tank, and from thence onwards to the sea the channel is an unfavorable subject for artificial appliances, on account of its very considerable depth and the heavy ex-

pense which would in consequence have to be incurred to lead the water, in low freshes, to the surface of the ground

The Kundalairoo, which passes close to Gudur, twenty miles south of Nellore, has a drainage basin of 1,240 square miles There is already a well built native anicut across it, and a channel feeding Gudur tank. Another channel from a branch of the same river to the Chennur tank is in progress, but the resources of the river cannot yet be said to be fully utilised, and it is desirable that they should form the subject of further investigation.

Bellary, Cuddapah, Kurnool —Turning to Bellary, Cuddapah and Kurnool, it will be seen, on reference to the Map, that the Toongabudra runs along the northern boundary of Bellary, and that, at a short distance below Kurnool, it is joined by the Kistna, also that all the other rivers in these districts derive their supply from what may be termed local drainage The Huggry, a branch of the Toongabudra, is an exception, but, though it comes from a distant part of the Mysore country partially within the influence of the south-west monsoon, its supply, owing to local circumstances, is scanty and uncertain, and it is consequently a very poor river as regards its power of irrigation On the Toongabudra, there are several anicuts and channels, and as that river derives its unfailing supply from the Western Ghauts, in which there is an abundant fall of rain, the cultivation under them is secure, and of course very valuable to the small section of the district to which their influence extends, when other sources of supply fail But they are small works, and do not offer any great field for improvement, to say nothing of the claim which the Madras Irrigation and Canal Company have on any of the Toongabudra water which is not yet utilised. It is on the Huggry that the Mauri-Convai works are contemplated by the Mysore Government, and, if they are carried out, of course even less water than before will reach the Bellary District. But it is hoped that, with the aid of various branches which will be unaffected by this scheme, there will be enough water left to supplement the supply of several considerable tanks. A project with that end in view has been under investigation, and may shortly be expected.

The other rivers in the three districts above-named are nearly all in the Pennair basin. It will be observed that the Chittravutty, the largest of its branches, and also most of the smaller branches, have been dam-

med across to form tanks, and some of these works are not only extensive, but exhibit a boldness of design which is worthy of high admiration With extraordinary natural disadvantages to contend against, the old native rulers have indeed done so much, that the difficulty now is, not from a number of promising projects, to select the best, but to find any projects which are worthy of consideration at all The Irrigation Company have already secured a right to the Toongabudra, but were it otherwise, the feasibility, in an economical point of view, of further utilising its water for irrigation from any point higher up than Kumply, is made more than doubtful by the extremely uneven and rocky character of the country skirting its course The other rivers have an uncertain supply, and though they are no doubt useful, in ordinary seasons, for the better supply of the tanks connected with them, it would be puerile to look to them as a safeguard against famines, for if the local rains fail, they fail also The only projects which have yet come forward, and which are likely to turn out well, are two anicuts and sets of channels on the Pennair, at the distances of from thirty to fifty miles from its source In the locality in question, there are already a series of tanks, some of which derive a partial supply from the Pennair by means of temporary dams across it, and small channels from it The proposed works will, no doubt, place the supply on a better footing, and though it may be difficult to prove that they will secure a return exceeding five per cent on the outlay, it is possible that that standard may be reached

Another project on a larger scale, and which is nearly matured, has been designed with a view to supplementing the supply of the Anantapoor and Bookacherla tanks by means of a channel from the Pennair, which would be led off shortly below the terminus of the other new channels above described, but these tanks are not in the valley of the Pennair, and the cutting through the water-shed would be of a very expensive character. This might not be an insuperable objection if an abundant supply of water could be counted on, but the reverse is the case The project is one of those which have been frequently pressed on the attention of Government by the Revenue Officers of the district and by the Revenue Board Plans and estimates for carrying it out were fully considered by Government in 1864, but were not approved, as they did not appear to be based upon sound calculations of the cost of overcoming the natural difficulties of the country. They were consequently returned for revision,

and this having lately been accomplished, the result is, I fear, that the project will have to be condemned. A project is also under investigation in Cuddapah District for improving the supply of two large tanks, but it is not yet matured.

As in Nellore and other districts, numerous improvements may be made to the existing tanks Many of them have silted up to such an extent as materially to impair their efficiency, and the attention of the Officers of the Department may be usefully occupied in restoring the capacity, where possible, by raising the embankments, when this can be advantageously done without submerging valuable land, or without incurring too great an outlay No one project of this nature can merit the special attention of the Government of India, but a number of well devised improvements, which may individually appear insignificant, are what such districts as Bellary, Cuddapah, and Kurnool, and indeed most of the other districts in the Presidency as well, want, for it is by means of them that the existing sources of supply can be utilised to the full extent, while the introduction of a supply from extraneous sources is beyond the power of any works, however great.

North-Arcot, Madras.—Turning now to North Arcot and Madras, I have to explain that various improvements are in contemplation The Government of India have already sanctioned the enlargement of the Red Hill and Cholaveram tanks, which derive their supply from the Cortilliar river, after it is joined by an important branch from the north-west, and also of the Chembrambaukum tank, which lies between the Cortilliar and the Palar river. These works, which are both in the vicinity of Madras, are now in progress, but the supply of the latter tank is dependent to some extent on that of other tanks, which cannot yet be considered to be on a satisfactory footing.

The Palar Anicut, and the channels leading from it, were designed with a view to improve the supply of nearly all the tanks—which are very numerous—situated between that river and the Cortilliar, as well as others to the north of the latter, but a very mistaken estimate was formed of the capabilities of the Palar, which, it was supposed, was in fresh for thirty-five days in the year on the average, whereas in reality, in some years it does not come in fresh at all.

Very exaggerated views of the capabilities for sustaining extensive systems of irrigation from the rivers on the Eastern Coast of this Presidency

have been entertained by the public, and have been persistently urged on the notice of Government Even the Commissioners appointed to enquire into the Public Works system in the Madras Presidency would have led the readers of their report* to the conclusion that the superiority of Tanjore over the districts adjacent to Madras was to be ascribed mainly only to one cause, viz, that capital to a vast amount had been invested in it, in bringing water to the fields, while they lost sight of the fact that Tanjore has extraordinary natural advantages, in possessing a deltaic tract of country traversed by a number of arms of the Cauvery, and that, moreover, no amount of capital expended in attempting to bring water to the fields in North Arcot or Madras could place these districts on the same footing with Tanjore, unless the source from which that water was to be drawn could, in the first instance, have been made as abundant and as unfailing as the Cauvery

It now appears that the Palar works do not answer the expectations that were formed of them, nor is it likely, when the project was drawn up, which was at a time when Officers had the greatest difficulty in obtaining money for any large works, that either they or the Government would have ventured to propose anything, had they foreseen that to secure a supply from the uncertain freshes of the Palar, a much higher scale of expenditure than had been customary on any other class of Irrigation works in the Presidency would prove to be necessary, and that the supply of that river was both so defective and so uncertain as it has proved to be But on the other hand, it has now to be argued that, imperfect though the supply of the Palar is, it is the only one, beside local rains, which can be made available for filling a number of tanks, many of which are of considerable size and importance · that the remunerative effect of Irrigation works is not the only aspect under which they are to be regarded, and that if Government derive an exceptionally high rate of profit from one system of works like those in the Deltas, they ought to be prepared to make a corresponding sacrifice, to bring up works less favorably situated to the highest standard of efficiency.

It must stand to reason, that it must be more difficult and expensive to draw a supply, for a given area, from a river which may be in fresh for ten days, in the year, than it would be if the freshes lasted for sixty days or more, as is the case even with the Pennair at Nellore, and that, as there are tanks in the Pennair Delta, as well as in the country affected by the

* Para. 284

Palar, it must be a much more costly and less remunerative undertaking to distribute water from the latter than the former, and the disproportion of cost must be still greater if the Palar is compared with the Cauvery, or the Godavery or Kistna Deltas, where the aid of tanks is unnecessary. Besides which, the country through which a channel from the Palar has to be carried, instead of being alluvial and possessing a fall suitable for the conveyance of water, is undulating and irregular, and the soil in many places is hard and even rocky. These disadvantages have stood in the way of the Palar works having been taken up in a comprehensive manner.

The channels, so far as they are carried out, are, I believe, in the right direction, but they cannot be considered as in any way complete. They have to be greatly enlarged before the tanks at a distance from the head can be supplied by them, and numerous masonry works are required to regulate the fall. The expense must necessarily be great, as above explained, but unless the tanks are to be left to the natural supply from local drainage, it will have to be incurred. One thing should never be lost sight of, viz., that our native predecessors have constructed the tanks for us, and that the cost of improving the means of irrigation to the part of the Presidency under consideration must be immeasurably below what an entirely new system of works would have proved.

The above remarks on the Palar are applicable also to the Cheyaur, and in a somewhat less degree also to the Poiney: these, with the Palar, being the three streams from which such improvement of irrigation, as is compatible with the condition of a limited command of water, is expected to be derived. The Poiney, though only a branch of the Palar, is better situated, from the direction in which it takes its rise, to receive a good supply, and the anicut which was constructed on it some years ago, with the channels under it, have, in consequence, proved more useful than the similar works on the other two rivers, although they have not come up to what was expected of them. There is already an anicut and a system of channels thereon on the Cheyaur, and two other projects connected with the same river have formed the subject of investigation during the past season. The existing project is not yet complete, and the surveys of the others have only been advanced to a stage which will enable a skilful Officer to use them as a basis for a general design of the works. I say skilful, for the alignment of channels through an undulating country, coupled with the necessity of providing for the supply of an enormous

number of tanks of various sizes, must necessarily be an intricate and difficult operation

The object and scope of the projects connected with the Palar and Cheyaur rivers, which have been under investigation, are fully explained in the report by Colonel Boileau, Superintending Engineer, 4th Division. Two minor projects are also particularised by the Superintending Engineer, but I have not yet had the means of forming an opinion of their value It is also designed to examine the north banks of the Cortilliar, and the Arnee or Nunnaveram river (drainage area, 500 square miles) which runs a few miles further north, and which traverses a tract which is well provided with tanks. Indeed, the surface of nearly the whole of the North Arcot and Madras Districts is covered with a perfect net-work of tanks Some of these admit of enlargement, others may be connected with rivers, and have their supply more or less improved; and though the irrigation in both districts must always be attended with uncertainty, the Government should, I think, take it upon themselves to undertake that the supply of water available in *average years* at all events should be utilised, even if the works required to effect this object do not promise to be sufficiently remunerative to entitle them to a grant from the "Loan" Fund

South-Arcot.—South Arcot is already well provided with the means of irrigation. A number of small but useful works have been carried out by the present Superintending Engineer, Colonel Foord, who has been connected with the district for the last twenty years; and two other projects, estimated to cost 54,800 and 11,000 rupees respectively, have lately been submitted by him, and have received the sanction of Government. The smaller class of rivers which traverse this district are better supplied than the Palar, while the southern portion of the district is bounded by the Cauvery, and derives a supply from it by a channel leading from the lower anicut

The Superintending Engineer is of opinion that there is no field left for works of the larger class, but that various improvements, of which he mentions several, may be superadded to the existing supply channels of tanks The improvements which have either been carried out, or which are in contemplation, may all be said to be of the same character. Small channels have in times past been led off from the river to various tanks, and in freshes the water is turned into them, in some cases by

means of permanent dams, in others by banks of sand and brush-wood. The old channels are imperfect works, and the tanks furthest from the head get an insufficient supply. The revenue of course suffers in proportion. The new works almost invariably comprise the construction of a masonry weir or anicut across the supplying stream, and of head sluices for the regulation of the supply. The old channels are either abandoned altogether, or modified, both as regards their sectional area and their levels, and distribution sluices are built for giving a proper share to the different tanks. It cannot be affirmed that the distribution is in all cases perfect, or that there is not room for further improvement in some of the works which have been executed under this Government, but judging by results, the small projects which have been carried out in South Arcot, may be looked upon as pattern works of their class.

It need not be supposed that the very high returns which are quoted from some of them are exaggerations. The storage room for the water had already been provided by the natives, the defects of the channels, as regards its supply and alignment and the distribution of water, had to be remedied before the people could get a proper supply for their fields, but these defects once removed by the judicious outlay of a moderate sum of money, the cultivation and revenue rise to the *maximum* of former years, or it may be beyond it, and, compared with the average revenue, this rise may be enormous, and indeed appear incredible to any one who has not the opportunity of scrutinizing and verifying the returns. For example, it is hard to believe that an expenditure of between 11,000 and 12,000 rupees on the Tirvady Anicut, in South Arcot, yields an annual return of 30,000 rupees. Of course, the more promising projects of this class are taken up in the first instance, a less paying series has then to be fallen back on, and, finally, we arrive at a stage when the improvements required may be of so expensive a character, that the results accomplished, though they may be very beneficial to the country, may not be highly remunerative to Government.

Salem.—In Salem, with the exception of tank improvements and the extension of irrigation from the Cauvery, no projects are likely to be brought forward. The Superintending Engineer mentions one which is now under investigation and which is estimated to cost 59,600 rupees. The formation of a large tank across the Pennair, near Kistnagherry, was suggested by the late Sub-Collector Mr. Thomas, and an Officer has late-

ly been deputed to survey the site. Several other projects have been proposed for examination by the Revenue Officers

Coimbatore.—The Cauvery forms the southern boundary of the Salem District and the northern boundary of Coimbatore. A project has been drawn up for the construction of an anicut across the river, at the distance of about twenty-eight miles from Erode, and for channels leading from the north and south flanks. The length of each in a direct line would be about twenty-five miles, though their actual course will be considerably more. An ancient rough stone anicut, a remarkable work of its kind, crosses the Cauvery at Nerinjepett*, and its restoration had long been advocated by the Revenue and Engineer Officers of the Salem District, but, prior to the year 1855, no detailed professional examination of the work, with a view to the preparation of a definite project in connection with it, had been made. In that year an estimate for restoring it and for a channel for the north bank was drawn up by Lieutenant (now Colonel) C. V. Wilkieson, but it was not sanctioned. The subject has been investigated afresh during the past season, and, with a view to gain a better command of the country, a site for a new anicut has been selected about four miles higher up the river than the old one. The ground to be traversed by the channels is very irregular, and is intersected by numerous drainages, which will necessitate the construction of a corresponding number of aqueducts and escapes. The project will thus be of an expensive character, but as a certain supply can be counted on from the Cauvery for the estimated acreage (about 20,000 acres, one crop only) without, it is believed, producing any injurious influence on the extensive irrigation in Tanjore, it is anticipated that the estimates will meet with favorable consideration. They are now nearly ready for submission.

The Calingaroyen channel, which is fed by the Bowany river, and which runs with an extremely tortuous course fifty-five miles in length, but in a general direction nearly parallel to the Cauvery, and at a mean distance of about half a mile from the south bank, has also been engaging attention. The anicut across the river, and the channel itself, are of purely native formation, the head sluice and several masonry works constituting nearly all the improvements it has received under European management. The levels of the channel and the distribution of water are extremely de-

* Poolumpett in the Trigonometrical map.

fective, the water being led to the fields by means of cuts in the banks, to the number of about 2,000.

Large estimates were submitted for sluices in 1855 and other works, but funds were not available This channel and others of a similar character under the Bowany, the aggregate revenue of which is about 2,00,000 rupees, are being placed in the separate charge of an Officer, who, after surveying them, will prepare the necessary plans and estimates for the various improvements which are required to place the irrigation on a satisfactory footing.

There are numerous other channels in the Coimbatore District, chiefly under the Amravutty and Noyel rivers, with an assessment of about two lakhs of rupees. I cannot at present speak with any confidence as to what extent they are capable of improvement, but it can hardly be doubted that the present arrangements for the distribution of the water are defective, and that some of the channels which are now supplied by means of temporary dams, or Corumboos, would be benefited by the construction of masonry weirs across the supplying streams On the Amravutty, there are twenty-two separate channels, of which six are supplied by the aid of temporary dams, and on the Noyel river there are twenty-four channels, all supplied by means of anicuts Colonel Ludlow wrote as follows, in 1854, on the subject of these works —"The Amravutty drains an area of upwards of 3,000 square miles,* including the northern slopes of the Dallee or Palaney range of hills, and is partially affected by the south-west monsoon. For a considerable portion of the year, therefore, it has a fair supply, and at times a very large one, but at the latter end of the season this frequently fails, and the crops suffer much in consequence, and the necessity arises for large remissions† in the worst cases "

"The area of drainage of the Noyel river (1,310 square miles) is much more circumscribed than that of the Amravutty, and owing to the confined extent and eastern aspect of Bolumputty valley, on which it has its source, the supply is anything but abundant." From Fuslies 1244 to 1260 (inclusive) the average annual assessment was Rs 1,38,694, the settlement only 66,197, the percentage of loss on the Ayacut being fifty-two, or rather more than half.

Mr. W. Fraser, C.E., was occupied several years ago in drawing up

* 3,500 square miles

† Average loss by remissions about 20,000 rupees per annum.

projects for the formation of extensive reservoirs, on the branches of the Cauvery which drain the Neilgherry Hills, but the plans and estimates have not yet been submitted. I learn, however, that the designs for the most important of the proposed reservoirs will be sent in without further delay A minor reservoir project was drawn up by Major Farewell, under the direction of the Superintending Engineer, 7th Division, Colonel Walker, and the prosecution of the work has been entrusted to Mr McIvor, Superintendent of Government Chinchona Plantations, who has engaged to raise a bund to the height of 140 feet, and to furnish the necessary appliances for disposing of the flood water, for the sum of Rs 25,000

Tanjore and Trichinopoly —In Tanjore and Trichinopoly the field for improvement is of a limited character. It has indeed been proposed to restore the old Ponnary tank, which was formerly fed by the channels from the Coleroon and Vellaur, and it is very desirable that an investigation into the economical practicability of the undertaking should be carried out, when an Officer can be spared for the purpose, but the attention of the Officers of the Department in these districts, will mainly have to be occupied in perfecting the existing system of irrigation under the Cauvery and Coleroon. In the Trichinopoly District there are several old channels, which may be considered as in a great measure independent of the great system under the Upper Anicut. They are of a similar character to the Calingaroyen channel, above described, and it is probable that the arrangements for the distribution of the water are capable of considerable improvement, and that it will be found advantageous to place an Officer in exclusive charge of them

In Tanjore, the regulation of the Cauvery and its numerous important branches, or rather arms, is now engaging attention The necessity of dividing the supply among the various channels, in proportion to the cultivation under them, has long been recognized by the Engineers of the district, though, from the inability of the Government to provide the requisite funds, it is only recently that a project for carrying this important operation into effect has assumed a definite shape As the Government are aware, Captain Mead has been engaged for a considerable time in carrying out the necessary preliminary surveys and investigations, which, owing to the enormous size of the rivers to be dealt with (the Cauvery for some distance from its head at the upper anicut being fully a mile wide), the total absence of reliable records of the culti-

vation under each river, and of levels showing the state of the channels at different periods, have necessarily been of a very laborious and intricate character. Captain Mead's first report has already been before Government, and the construction of regulating dams across the Cauvery, at the heads of three large arms, the Codamoorty, the Arasalar, and the Veerasholen, and across the heads of the arms themselves, has been decided on Plans and estimates may shortly be expected for the works which are still required for the control of the Cauvery itself. They are designed with the two-fold object of shutting off dangerously high floods from the Delta, and of effecting a fair apportionment of the ordinary supply between the Cauvery and the Vennaur, the cultivation under each of which is about 350,000 acres It is not considered safe to discharge into the Coleroon more than a limited supply of the surplus flood water, and as, moreover, a large quantity of water is required at times in the Delta, to make up for the deficiency below the ordinary standard at other times, —a contingency very liable to occur in consequence of the fluctuating character of the freshes,—the regulating works have to be designed on a scale far more extensive than any work of the kind that has been undertaken in this country.

The Superintending Engineer, Captain Oakes, does not anticipate that any great increase of cultivation, and, therefore, of revenue, will result from the improvement of the deltaic rivers, but he explains that the supply of the lands will be better regulated, and, therefore, more constant in seasons when the monsoon is not very favorable, and that the waters during floods being more fairly distributed, according to the capacity of discharge of the various rivers, will do less injury than they now do, and that a large saving in temporary repairs and in closing breaches will in consequence be effected

The regulation of the Cauvery and the larger streams in Tanjore once effected, the next step will be to improve the system of distributing the water to the smaller channels, or rather to *institute* a system, for at present there is none. It will be a task that will not be willingly taken up by many Officers in the Department, as, independently of various engineering difficulties in their way, arising from the variable character of the supply of water, they will meet with great opposition from the influential cultivators, who would not only present hundreds of petitions against the introduction of the new works, but would take more active measures to

check them by bringing actions against the Superintending Engineer in the Law Courts This is no imaginary evil as the Government are well aware That some day or other it will be necessary to put a stop to it by legislation, if any real improvement on the old native systems of irrigation is considered essential, I feel perfectly satisfied, and, indeed without legislation to support the Public Works Officers in Tanjore, it will be useless, as has been already brought to notice on several occasions, for them to attempt to introduce any real improvement in the present defective style of distributing the waters of the Cauvery.

Madura —In the Madura district, the existing supply of water is already fully utilised There are numerous small channels from the Vigay and the minor streams in the district, but they are far from sufficient for the wants of the people The importance of the Periyaur scheme, which was recently under the consideration of Government, and which would throw an abundant supply from an entirely new source into the most arid part of the district, can hardly be over-estimated. The project has been investigated by Captain Payne and Captain Ryves, the latter Officer being the originator of the scheme, and a report has been submitted explaining the nature and object of the proposed works Some delay occurred in following up the investigation in consequence of the demand for Officers in other directions, but two Officers have lately been appointed to open out roads, and to make the further preliminary investigations which are required, preparatory to the submission of the estimates for the approval of the Government of India.

In briefly describing the nature of the project, I can only recapitulate what has been stated on other occasions It is to turn the supply of the Perryaur, a river which drains an area of 250 square miles of hilly country within the influence of the south-west monsoon, over the edge of the ghauts, which overlook the plains of Madura The bed of the river is about 165 feet lower than the lowest point in the ghaut, at the spot selected for the diversion, and at the distance of about four miles from it. It is proposed to raise the surface of the water to the height of about 150 feet above its lowest level, and to cut through the saddle to a maximum depth of forty feet. The site for the embankment is favorable as regards the formation of the ground, and the quality of the soil is also well suited for the construction of a water-tight embankment, but the locality has the reputation of being extremely unhealthy during the hot weather (15th

February to 15th June),—that is at the time of the year when the progress of the work would be least liable to interruption from floods, —and the ground is covered with dense jungle The cutting through the saddle would be mainly in rock, and Captain Ryves has carefully considered the relative cost and difficulty of the embankment and cutting with various alternative heights and depths respectively, before coming to a conclusion that the preference should be given to those which provide for the formation of a reservoir 150 feet deep Further enquiry may possibly lead to a modification of this arrangement, but not to any extent The project is a noble one, and though there are formidable difficulties in the way of its execution, it is hoped that by perseverance and good management it will eventually prove successful The sanction of the Government of India to the large outlay it will involve cannot of course be expected, until the complete feasibility of the undertaking is established, and it is with that object in view that the two Officers above adverted to, have been deputed to open out roads in the vicinity of the proposed works, and by thus attracting labor on a small scale and accustoming the people to frequent a tract of country at present shunned by them, to allow of a judgment being formed as to how far the contemplated operations on a larger scale are practicable.

An ancient lake on the Pulney hills attracted the attention of His Excellency the Governor during his recent visit to Madura, and a rough survey by the Superintending Engineer shows that if it were restored it would be capable of holding a supply of water equal to the irrigation of 8,000 acres The ground in the vicinity, which is 7,000 feet high above the sea, is described as being admirably adapted for a Hill station.

Tinnevelly.—In Tinnevelly, a project for utilising the surplus water of the Tambrapoorni river has been drawn up, and the estimates have lately been submitted for approval to the Government of India. This river, though of insignificant length, derives a plentiful supply from the south-west monsoon, which breaks with full force on the ghauts, in which the river takes its rise The irrigation under the river is very important. It is carried on by the aid of a succession of anicuts (seven in number) and channels, all of native workmanship These old works have been maintained at a trifling cost to Government, and yield a revenue of about six lakhs of Rupees. The project recently submitted provides for the irrigation of a strip of country to the north and south of the river, from the

terminus of the existing channels to the sea The northern channel, which ends at Tuticorin, will be twenty-six miles long, and the southern channel to Tritchendoor twenty-two miles The area to be irrigated is estimated at 32,500 acres, and the returns Rs 1,43,000 on the estimated outlay of about eight and half lakhs of rupees

The improvement of the irrigation under the minor streams in Tinnevelly will also merit attention

I have now in a manner described the condition and prospects of the irrigation in every district in the Presidency excepting Malabar and South Canara, which, in consequence of the abundant supply of water they receive from the south-west monsoon, do not require to be noticed. A few general remarks may be added with advantage

The Government of India will perhaps be disappointed to learn that the improvements which are in contemplation in this Presidency are of a limited and even insignificant character, compared with the great projects which are coming before them from other provinces But the fact is, that in no other part of India had so much been done for the development of the resources of the country by the old native rulers The further South one goes, and the further the old Hindoo polity was removed from the disturbing influence of foreign conquest, the more complete and elaborate was the system of agriculture, and the irrigation works connected with it The execution of such works appears to have been considered a religious duty by the people Not only has almost every available source of supply, within their power of mastering, been utilised to a very great degree, but in many instances they even carried out the works far in advance of the supply. The vast system of tanks which cover the face of the country, and which represent an almost incalculable expenditure of labor, have very generally been constructed not only to provide for the storage of the ordinary rain-fall, but also that of exceptionally favorable years.

Not only, too, were all favorable sites for the construction of tanks eagerly sought for and turned to the best account, but unfavorable sites also, where success was only to be attained by the display of very considerable constructive skill, and by the most profuse outlay of money and labor, or at least of labor. The Natives thus constructed numerous tanks with embankments three or four miles long, and thirty to fifty feet high,

and revetted on one or both sides with rough stone ; with sluices for the distribution of water, and with escapes for the discharge of exceptional floods, some of them of great length and of massive construction. Their sluices are remarkably well adapted for the distribution of the water under a variable head, and are, moreover, eminently calculated to prevent the occurrence of accidents from the careless and imperfect management under which they must generally be placed.

So anxious were the Natives to avail themselves to the utmost of all available sources of supply, that they constructed many tanks in situations where it was impossible that a proper supply of water should reach them ; and it is now common to meet with works of the kind which at a later period have been purposely allowed to fall into decay. Other tanks have also been rendered useless by becoming silted up. The process though very generally a slow one, is nevertheless sure, and of course, in cases in which the drainage water has, before reaching the tank, to pass over a tract of alluvial, or other, soil which will yield easily to the action of a current, the deterioration may be rapid. In such cases, it is a mere question of time for the soil which is thus distributed over the bed of a tank, to become more valuable for the cultivation of dry crops, than the ground outside, with a diminished supply, for the cultivation of rice. I lately saw a tank, near the head of the Pennair, a short distance to the north of Nundydroog, which had evidently been abandoned from this cause, the old bed having become raised about twenty feet above the level of the ground outside. Many instances might be given of tanks having been given up either from the same cause, or from the totally inadequate supply of water they received for the irrigation of the lands under them. Of course there are cases where tanks may have given way from neglect, or from their not being provided with proper means for the discharge of surplus water in heavy floods, but the cases in which they have purposely been allowed to go to ruin are, I believe, more numerous, although, from the works having been abandoned many years ago, the cause may not have been within the cognizance of the present generation. Projects for the restoration of old tanks must therefore be received with caution. It by no means follows that because an old tank bund may have been built on a large scale, and because comparatively little labor and expense are required to restore it, its restoration may be a judicious proceeding; in many cases it would certainly be the reverse.

The Natives also carried direct irrigation by means of river channels, or by channels and tanks combined, to a tolerably high degree of perfection There is the Cauvery system in Tanjore, which is the completest thing of the kind in India, and the Tambrapoorny system in Tinnevelly, which, though on a much smaller scale, exhibits, with regard to the anicuts across the river at the heads of the various channels, very considerable constructive skill There are numerous works of a similar character on the Toongaboodra in Bellary, the Cauvery and its branches, and on nearly all the minor streams in the Presidency With regard to the alignment of channels, the natives having only the means of judging of levels where they could see water actually running or standing, failed when they ventured to enter irregular ground They could not go far wrong as long as they kept parallel to a river, but if a ridge or a succession of ridges had to be cut through they got into difficulties. Consequently, there are many old channels which have been abandoned, either because the difficulty of conveying the supply to the required point turned out to be more formidable than had been anticipated, or because the point of delivery may have been on an impracticably high level. On the whole, the native channels are an inferior class of work to their tanks. The distribution of water, though probably arranged originally on tolerably fair principles, is every where, under the old channels, of the most defective kind; but until definite proposals for rectifying existing abuses can be brought forward, it is useless to enlarge on this point.

It will be seen from the above remarks that the Natives had made great advances towards the attainment of a complete system of irrigation throughout this Presidency. But though many of their works exhibit considerable boldness of design, and no small degree of constructive excellence, they failed in mastering the largest class of rivers, where no foundation but sand was to be found for the construction of masonry dams Thus it required the aid of British Engineers to construct anicuts across the Cauvery in Trichinopoly and Tanjore, and across various other rivers in the low country bordering on the eastern coast. Once they were finished, but two great works remained to be done. I refer to the construction of dams across the Godavery and Kistna at the heads of the deltas of those rivers, and to the opening out of a system of channels from them. The Natives had altogether failed to place the irrigation of the rich lands in the deltas on anything like a secure footing They had in-

leed excavated a number of channels, and on the Kistna, tanks had also been formed, but in consequence of the great variation in the surface level of the rivers, and the impossibility of conveying the water to the surface of the country during low stages of the supply, the cultivation was of the most precarious kind, and the districts would be suffering from famine when an abundant supply of water for the irrigation of the whole area was running uselessly into the sea. The anicuts at Dowlaishweram and Bezwada, with their subsidiary channels, have changed all this, but the irrigation of a district cannot be perfected in a single generation, and the completion of the works, with the introduction of improvements in the very imperfect mode of cultivation now prevailing in these districts is, beyond all comparison, the most important work that remains to be carried out in this Presidency.

Smaller works have been executed with good effect in Nellore, others are in contemplation there, and various projects are also under consideration for the improvement of irrigation in other parts of the Presidency, as I have explained in the body of this report, but they are all of an insignificant character compared with the works in the Godavery and Kistna Deltas. Nothing at all to be compared with them is likely to be brought forward. Every deltaic tract of country of considerable size is now taken up. There are only two rivers, the Cauvery and Toongaboodra, which derive a supply from the south-west monsoon, and which pass through any considerable extent of non-deltaic country within the limits of this Presidency, in consequence of that supply being the only one which is of so unfailing a character, as to constitute a source for any great extension of irrigation, any large future projects must be limited to those rivers * But owing to the hilly character of the country bordering on the Cauvery, from its source to the eastern boundary of the Mysore territory, and some distance beyond, no extensive works are to be looked for from it, and, as regards the Toongaboodra, the supply, which moreover is far less regular than that of the Godavery and Kistna at the heads of the Deltas, has been placed at the disposal of the Irrigation Company,—with what result the Government are aware.

The most important new projects under consideration at present are the Perryaur scheme in Madura, the Sungum project in Nellore, and the

* Unless we include the possible opening out of a second system of channels from the Godavery and Kistna, at Polarum and Chintapully.

Rooshkolia project in Ganjam. Any others which may be brought forward are likely to be of secondary importance. The improvements to existing works, which will from time to time be proposed, will however be very numerous. They will embrace the regulation of the Cauvery and its branches in Tanjore, the construction of head sluices to the Tambraporney channels, and the rectification of defects of alignment and in the distribution of water from them, as well as from various other old channels. Tanks also will in many cases admit of improvement. But, with few exceptions, such improvements, though important as a whole, and though they will involve a considerable outlay, will not individually merit the attention of the Government of India.

No CCLIV.

WATER SUPPLY OF CANTONMENTS.

NOTE *upon a source of water supply for our Indian Stations for drinking and Culinary purposes* BY MAJOR J. G. R. FORLONG, *Superintending Engineer, Rajpootana, F R S.E., and Assoc. Inst C.E.*

FROM a perusal of Dr Parkes' great Standard Works on Hygiene, and the various reports on water which the Government of Indian is constantly circulating, it appears to me that we ought now, in all stations where we have permanent barracks or buildings with masonry roofs, to collect all our rain fall

It may be laid down roughly as a rule, that the rain which falls over every European's roof is sufficient for all his drinking and culinary purposes during the whole year.

I was much struck with the proximity to truth of this rule, on two visits I made to Venice and some other Continental towns within the last few years. Venice wholly relies upon the rain which falls on the roofs of her houses, and Dr. Parkes shows how she catches, filters, and stores this, and states that "it remains cool, limped and pure through out the year"

No water equals rain water. It is evaporated from nature's one great and only source, and even chemists almost allow us to call it perfectly pure up to the moment it reaches our various gathering grounds.

The purer these then are from organic and inorganic matters, and the faster it can be made to pass over such, into our reservoirs, and

there be shut up from light and heat, the purer we shall have our annual rain supply

Now in India, if we reject the first floods of our monsoons, we ought to be able to collect our rain fall with far less impurities than in parts of Europe where the rain falls in showers distributed all over the year, but the question arises, can we, in this hot climate, preserve pure what we thus store up?

I see no reason why we should not At all events we can do so if we store as deeply as we now draw our water from, for a well is, after all, only a reservoir into which rain water, with more or less of impurities, has percolated

Our pure rain water can therefore be similarly stored, and with ordinary precautions ought to be very much better Mr. E Chadwick says that "in Spain the water, collected and stored in covered tanks, is valued according to the length of keeping, as old wine" I fear our soldiers will never be persuaded to accept it as such, or our stations would indeed become healthy in spite of very great impurities in their waters

If the principle I advocate or, I would rather say, seek to ventilate, be acknowledged, then it is clear from Drs F N Macnamara's and May's elaborate reports on the absence of good potable waters in many of our large stations, especially Nusseerabad, Morar, Agra, Delhi, &c, we have there the same easy and not very expensive remedy.

Taking then the Government of India's Block plan of accommodation for a Regiment of British Infantry,—I find the following roof areas—

	No		Length		Breadth		Area sq ft
Half company Barrack,	16	×	200	×	60	=	192,000
Full ditto,	2	×	400	×	60	=	48,000
Married quarters,	8	×	230	×	60	=	110,400
Canteen,	1	×	190	×	50	=	9,500
Quarter Guard,	1	×	70	×	30	=	2,100
" "			90	×	45	=	4,050
Band and rear Guard,	1	×	190	×	50	=	9,500
			Total catchment area,				375,550

In Nusseerabad the average rain fall may be taken at 21 inches.

Our annual supply will therefore be in average years 657,212 c feet,

which at $6\frac{1}{4}$ gallons per cubic foot, = 4,262,318 gallons

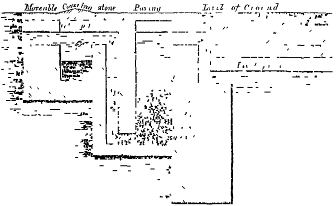
Available per day, = 11,648 gallons.

And taking a European Regiment and its families, &c, at 1,500 souls, each will thus get, per day, $7\frac{3}{4}$ gallons.

Professor Parkes says half of this would suffice, if other sources give ample for washing, &c.

The tank necessary to contain such water would require to be 210 × 210 × 15 feet, but more would be required for surplus falls, and there should be of course a surplus escape besides

The ducts and face of tanks might be slate or fine closely fitting slabs, run in with hydraulic cement, and backed in the usual way with fine puddle-clay, concrete, &c. There would be a filter and catch pool for the water before entering the reservoir.



I would propose four reservoirs for each regimental group, situated nearly as shown in accompanying block plan.

Of course, no collection of water would be allowed, or is necessary on roofs, the water would run, as now, down the usual amount of side pipeage and be conducted into a duct running along the base, (a little distant if thought desirable) of buildings, and leading to a "Main," and hence to the reservoir.

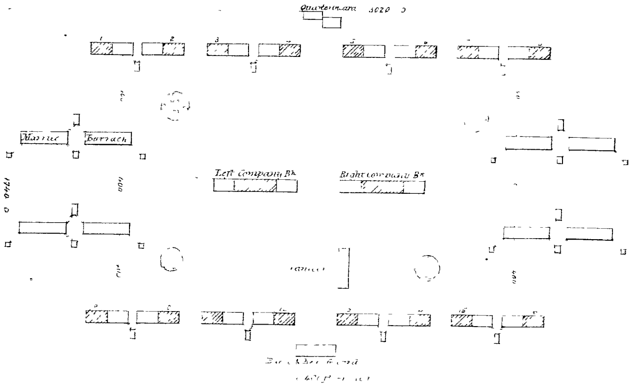
The reservoir need not be sunk too deep, but should be roofed over and kept as cool as possible.

The water should be drawn up by a good English pump or pumps, if only one, then it should be worked by cattle. A Force pump might be used to fill a daily supply tank kept in each barrack, under a sentry, if thought necessary. We should, I believe, save money by this arrangement, and do away entirely, as regards our drinking water, with the Native Bheesties, and their too often dirty and disease-giving bags.

J. G. F.

WATER SUPPLY OF CANTONMENTS.

(*Block Plan of Barracks for a Regiment of E I*)



No. CCLV.

EMBANKING THE HOOGHLY.

(2nd Paper.)

From the VENERABLE J. H. PRATT, *Archdeacon of Calcutta, to the Joint Secretary to the Government of Bengal, P W. Department, Irrigation Branch.*

Dated Berhampore, the 7th December, 1868

HAVING just received from you the information I have asked for, in addition to what you furnished me with in your letter No. 259 I, dated 7th October, 1868, communicating the wish of the Government of India that I should give an opinion on the probable effect on Calcutta of embanking the Hooghly from the Sea in the event of a cyclone, like that of October 1864 occurring again, I now have the honor of replying to the question raised.

I have no hesitation in expressing the opinion that the safety of Calcutta would be greatly imperilled by embanking the Hooghly from the seaboard to its neighbourhood, to such a height as to confine the waters within the channel of the river, should such a cyclone as that of October 1864 again occur, and, as I learn from the information just received from you, that the tide rises as high at Hooghly Point as at Kedgeree, I consider that the same hazard will be incurred by embanking even from Diamond Harbour up to the neighbourhood of Calcutta

The reason for my holding this opinion I will give further on. It is not every cyclone which would be made thus dangerous by embanking. To show when a cyclone may produce a dangerous inundation, if the river were embanked, I must enter somewhat at length into the phenomena of the tides and of cyclones.

The great tidal wave is formed in the wide ocean by the moon drawing up the waters immediately beneath it, and allowing them to subside again as the moon passes on towards the west. The vast wave thus produced is propagated up the Bay of Bengal to the mouth of the Hooghly, and, as deduced from the information just received from you, the level of the water rises from low to high water at springs through an average of 14 feet at Kedgeree, the same amount, 14 feet, at Hooghly Point, and 10 feet at Calcutta, this last occurring nearly four hours after the rise at Kedgeree The weight of the rising water presses downwards through the water below, and pushes up the water in front, and thus the wave is propagated up the river, occupying less than four hours in reaching Calcutta, about 80 miles off Not that the water itself travels so fast, but the communication of pressure through the water causes the elevation of the water, or the wave, to travel at that rate The variations of the river in width, depth and direction, are such as to baffle every attempt to find the rise of the tide at Calcutta from that at Kedgeree, by mathematical calculation But we have the problem already solved for us by observation, and the numerical results above-mentioned are most important facts, of which I shall make use at the close of this letter

The cyclone and its wave are formed as follows:—Over a wide portion of the ocean (say over some square miles to the west of the Andamans) an unusual amount of evaporation creates an ascending current of air over the whole tract To prevent the exhaustion which would follow, air rushes in from all sides, and after a while, violent winds from all quarters and from great distances move in towards the centre Any person who understands the established principle on which the direction of the trade winds is explained, will see at once that, supposing he is moving with the wind from whatever quarter (except due east and west) with his face towards the centre, the wind will get a set to the right of the centre, if the storm is north of the Equator, as our storms are, owing to the rotation of the earth on its axis.

This effect of the inrushing winds is to give the central parts of the storm a rotatory motion from east through north to west, and so through south to east again, or in a direction opposite to that of the hands of a watch lying with its face upwards. The wind does not come in from all sides with exactly the same force. Owing to this, the resultant effect, which in

the cyclones which visit Calcutta, is towards the north, moves the whole storm bodily along in that direction The winds as they are caught in the storm, will evidently blow round in a spiral and be centripetal, and as they approach the central parts will move upwards with the vertical stream which, in the first instance, originated the storm As the air is here moving violently upwards, the atmospheric pressure on the sea is diminished, and the barometer falls If the barometer falls as much as 2 inches, the sea will rise somewhat more than 2 feet (mercury being about thirteen times the density of sea water), being pressed up by the ordinary weight of the atmosphere outside the storm, acting through the sea

This rise of the sea on the central part of the storm is called the storm wave It is of a generally circular form, the storm being of that figure, and subsides in parts as the storm is leaving, but is continually forming in front as the storm is advancing

This wave, however, is raised higher by another cause The winds rushing in violently over many hundred square miles, in a spiral vortex towards the centre, heap up the water by friction. This increases the height of the water in the centre above the height measured by the fall of the barometer. It is evident that this cause can act only in the open ocean as soon as the cyclone reaches the land, its effect is altogether lost, as there is no water, except the narrow strip of the river, for the vortex of wind to heap up Moreover, if the centre of the storm does not move along the exact line of the river, the water is not much raised by the fall of the barometer, and, even if it does, the rise from this cause, at most is only about 2 feet. In fact, as soon as the cyclone reaches the continent, the generation of the storm-wave above described ceases, for the causes cease to act, or act very feebly. The cyclone travels on over the continent, but the storm-wave, when once it has reached the mouth of the river, can no longer be generated as before, and can be regarded simply as an unusual rise of water, caused by the process which has been going on in the open sea before the storm reached the land.

This unusual rise of water at the mouth of the river will, by its pressure, generate a wave up the river, precisely like the tidal wave, lasting for a longer or shorter time, according as the rise caused by the storm-wave at the mouth of the river, lasts a longer or shorter time than the rise of the tide lasts. This wave I call the river-wave, to distinguish it from the storm-wave at sea from which it originates. This wave moves

up the river at about the same rate as the tide, if confined within the channel as the tide is If it overflows the banks, as was the case in the cyclone of October 1864, its velocity will be affected A writer in the printed report forwarded to me (page 124) mentions this fact, and says is "appears anomalous" that it moved slower than the tide would have moved. But the enormous overflow of water over the banks all the way up would greatly modify the pressure in the direction of the river, which generated the river-wave The sudden vent which the waters thus found sideways would establish side-currents, which would have this effect of retarding its upward motion. While the storm-wave is at sea, it is continually being generated by the storm itself, and the wave and the calm or central part, move on together. But as soon as the storm reaches the land, and the causes which produce the sea-wave cease to act, or act feebly, as I have shown, the river-wave and the calm, or central part of the storm, move independently of each other; they start together when the storm reaches the land, but after that have nothing in common · this explains the fact mentioned in the printed Report that the calm and the wave in several instances reached the same place at different times, one before or after the other, according as it was affected by the local winds

I think everything tends thus to show that no storm-wave is generated in the river, but that the storm-wave which arrives from the sea at the mouth of the river, simply generates a wave up the river, which moves according to its own law of wave or tidal motion, more or less modified in its course by the winds it encounters. It appears, moreover, that the storm-wave at sea cannot in itself be an object of any formidable height, for the fall of the barometer at most cannot produce a rise of more than 2 or 3 feet. how much this may be increased by the vortex, I cannot say, but I cannot conceive it to be very great. The storm-wave, then, not being very high, it might be generally expected that the river-wave would not be formidable. This indeed accords with the known fact that cyclones, as violent as that of October 1864, have appeared to have no storm-wave, or none of any importance.

How, then, can the destructive effect of the storm-wave of 1864 be accounted for? I conceive that this arose simply from the course which the centre of the storm took, viz, *west of the river*. In consequence of this, the wind at the mouth and lower parts of the river was south, or had south in it the whole time that the storm was passing up. The storm

moved at nearly 20 miles an hour northerly, if the whole storm was 250 miles in diameter, this wind would be blowing into the river, and sometimes with tremendous violence for about 12 hours. In the printed Report it is stated that, on the north of Saugor Isle, the water was raised hardly above the usual level. This accords with the suggestion I have made that it was the wind from the south which crowded up the water in the contracting part of the river, the island would protect the part immediately to the north of it from this influence. The pressure on the water would crowd up the waters in the contracting cheeks of the river prodigiously, and might produce the recorded rise of 30 or even as much as 40 feet (Report, page 33) which generated the fearful wave which passed up the channel and poured over the banks. Had the centre of the cyclone passed up on the east side of the river, the wind would have been north or northerly in the river, and none of the disastrous effects of 1864 would have occurred. Though, then, many cyclones may occur, unaccompanied by a dangerous storm-wave, another may occur like that of 1864, passing to the west of the river, and we must draw our precautions from the data of that storm.

Since, then, these are facts that (1) the water rose in the storm of 1864 at the mouth of the Hooghly 40 feet, and that (2) a tide there of 14 feet produces a rise of 10 feet at Calcutta, the river-wave of the cyclone, had it been confined by embanking, would have produced at Calcutta a rise of something like 29 feet. This, whether it should occur at springs or not, would be fearful, especially, too, as these storms last some hours. The data also show that the ordinary spring tide at Hooghly Point rises through 14 feet. The water in the storm of 1864 rose there 27 feet (Report, page 35). Had then the banks been high enough to confine the river-wave within the river channel, it would have produced a wave as much as 19 feet high on reaching Calcutta, which would of course be dangerous to the safety of the city.

Note by Lieut.-Colonel F. H. Rundall, R. E., *Chief Engineer, Bengal, Irrigation Branch.*

Dated 4th March, 1869.

Letter from the Government of India, P. W. Department, No. 52 I., dated 11th February, 1869.

With this letter is forwarded copy of a Despatch from the Secretary of

State, enclosing a further opinion by Professor Airy, relative to the effect which embanking the mouth of the Hooghly would produce on a cyclone-wave, and the Report from Archdeacon Pratt, to whom the matter was also referred, is asked for at the same time

I will notice the latter first The phenomena attending a cyclone-wave are very clearly described therein, but I am not quite prepared to admit that the arguments deduced therefrom are conclusive, and that, because a certain proportion of rise and fall in the tidal-wave is maintained at various points on the river, the same or a similar proportion must necessarily hold good in the case of a cyclone-wave There are certainly not data sufficient to say whether the storm of 1864 was the greatest in *intensity* that has been known in this locality, or that it occurred under the most extreme conditions possible for producing the greatest injury, but from the recorded accounts, such would *seem* to have been the case.

Archdeacon Pratt explains the reason why the "riverwave," as he terms the phenomenon in contradistinction to the "stormwave," generated at sea, moves at only half the rate that the daily "tidalwave" does, by the fact that the vent which that wave found over the land "greatly modified the pressure in the direction of the river, and by establishing side currents, retarded the upward motion." I confess that this explanation *does not carry conviction to my mind, because I am not satisfied* that the volume which passes between and below the level of the natural banks of the river would be at all affected as regards its transmission It does not appear that the phenomenon of the "tidal-wave" was retarded on that day, and therefore it may be assumed that it proceeded at its usual rate. The fact of the cyclone or "river-wave" travelling at only half the speed, leads me to the conclusion that it is mainly dependent, as I remarked in my first paper on this subject, on the path and intensity of the wind.

Though the arrival of the wave was not simultaneous with that of the centre of the storm at every point, it is possible its acceleration or retardation depended on the direction which the particular reach of the river where the difference occurred, bore to that of the wind For instance, it will be easily understood how differently the upward direction of a wave in the reach between Diamond Harbour and Hooghly Point would be affected by the wind blowing from the west instead of from the east. From the recorded facts, it appears that the highest wave was experienced

at Cowcolly Lighthouse, that 6 miles *below* that point, the wave was 5 feet lower, and 3 miles above it, it was only 1 foot lower, while on the opposite *shore*, the water appears from the Cyclone Report, to have been raised hardly above the usual level It therefore seems to me scarcely possible that if the "river-wave" moved wholly independent of the wind, and was governed by the same laws that influenced the tidal-wave, there could have been such extraordinary differences of level. Archdeacon Pratt's explanation of this circumstance cannot, it seems to me, hold good, viz, "that it was the wind crowded up the water in the *contracting* part of the river," for the greatest height of wave was experienced at Cowcolly Lighthouse. I think Archdeacon Pratt must have misread *Saugor Point* for the *north of Saugor Island* At the former place there was no preceptible elevation in the surface level, owing to its being almost in the open sea, but the north of Saugor Island was inundated 10 to 11 feet. At Middle Point, 17 miles, higher up, the wave was 4 feet, and at Diamond Harbour, 13 miles higher still, it was $4\frac{1}{2}$ feet lower than at Cowcolly. The contraction of the *River Proper* may be said to commence at Middle Point.

Above Diamond Harbour, the Hooghly ceases to be funnel-shaped and preserves a tolerably uniform section, but the Roopnarain, which seems to be more properly the continuation of the Diamond Harbour Reach, has a funnel form, and that river would therefore be exposed in a greater degree than the Hooghly to the peculiar action resulting from that form—a point which is discussed in Professor Airy's letter.

The *reputed* rise of 40 feet quoted by Archdeacon Pratt from page 33, Cyclone Report, cannot be taken as a *recorded fact*, it having been merely the conjecture of a Pilot on board the ship *Martaban*. The actual ascertained highest rise immediately opposite that ship's position, viz, at Cowcolly Lighthouse, was 30 feet above low-water level Assuming then that the cyclone-wave was influenced by the same law as a tidal-wave, and that there would be a proportional elevation produced at Calcutta, the total rise there above low-water, would be 21 instead of 29 feet The greatest rise in the high spring tides takes place in the month of June, when it reaches 13 feet at Calcutta, so that $21 - 13 = 8$ feet would be the greatest height of water which it could even be necessary, under that supposition, to guard against. To provide protection for that elevation of water would neither be difficult nor entail an unreasonable expenditure

Professor Airy's letter confessedly deals in such a general way with the point at issue that it cannot be taken as decisive of the question, indeed, that gentlemen expressly reserves a definite opinion on the subject in the absence of observed and recorded facts, a more intimate knowledge with which, he observes, might possibly lead him to a change of opinion.

The question, after all, resolves itself principally into one of cost, and viewing the matter in its extremest light, viz, that the elevation of the river at Calcutta would be equal to what took place at Cowcolly Light, the same defences which had been completed and remained intact to the South of that place, would of course be sufficient for the protection of the upper reaches of the river.

The dyke in its most expensive section cost Rs 16,000 per mile. On an average from the mouth of the Roopnarain to Calcutta, it would probably not cost more than Rs. 12,000. The distance is 40 miles to Calcutta by the Hooghly, and as much more by the Roopnarain and the Damoodah, say 100 miles in all, which would give 200 miles of embankments, costing, at the above average rate, Rs 12,000 × 200 = Rs. 24,00,000, or at the extreme rate of Rs 16,000 per mile = 32 lakhs of rupees. To that sum would have to be added the cost of sluices, amounting perhaps to half as much more, or say the project might, in round numbers, cost 50 lakhs, or half a million sterling Let this sum, even were it doubled, be compared with that recently expended on a few miles of the Thames embankment, and at the same time let the relative importance of the two works be taken into consideration, before it is decided to dismiss the project as impracticable either from an engineering or a financial point of view.

From the Venerable J H PRATT, *Archdeacon of Calcutta, to* LIEUT -COLONEL F. H. RUNDALL, R E, *Joint Secretary to the Government of Bengal P. W. Department, Irrigation Branch.*

Dated the 23rd April, 1869

In January last Colonel Dickens expressed to me a wish that I should add a postscript to my former letter to you, dated the 7th December last, to show what might be the probable effect upon Calcutta were the river Hooghly embanked from the sea to Diamond Harbour, and not from Diamond Harbour to Calcutta, so as to confine the river-wave within the river channel in the lower part of its course, in the event of another

cyclone occurring like that of October 1864 To take up this question requires data regarding the present embankments about Diamond Harbour With these you have now furnished me, and I have the honor of laying the result before Government.

The question is somewhat more difficult of solution than the one formerly proposed to me, even were the statistics of the Cyclone of 1864 better known than they appear to be. But I will give the best solution I can I will here observe that, in a problem of this description, which concerns a project in which the safety of such a city as Calcutta is involved, we should not work on average phenomena, but should take the most unfavorable circumstances which are known to have occurred in past cyclones, as these circumstances may occur again It was on this ground that in my former letter I took the height of the river-wave off Kedgeree to be 40 feet, as a Pilot had reported as follows —" In tracing the drift of the ship *Martaban* on a chart, I find that the storm-wave must at least have risen 40 feet to have carried me across these sands" (Report, p 33), although another statement (p. 113) makes the height only "28 9 feet above low water mark So also of the two statements regarding the height of the river-wave at Diamond Harbour one makes "the height of the wave over high water mark spring tides not less than 25 feet" (p 36); whereas another (p 120) states that "the height of the storm-wave at Diamond Harbour was 4 58 feet over the top of the bund," which from the data you have now furnished me with,—(*see* next paragraph,) is only 11 52 feet above high spring tide in that month (October). The problem I have now to solve depends upon the data of the Cyclone at Diamond Harbour, and I shall again take the least favorable statement, viz., that which produces the largest results, which in this case will be the latter, viz., that the river-wave rose 11 52 feet above high spring tide mark.

And I may here remark that other reasons occur to me for giving less credit to the first of these accounts than to the second. For, by comparing the statements in pp. 112, 36, 122 of the printed Report of the Cyclone, it will be seen that high tide is said to have been due on the Cyclone day at 12*h*. 25*m* P M., 10*h* 30*m*. A.M., and 4*h*. 37*m* P M. at Cowcolly Lighthouse, Diamond Harbour, and Calcutta. This is impossible. The second must be low water, and not high.

From the documents you now send me, I select the following data —

Diamond Harbour		*Strand, Fairlie Place, Calcutta*	
Top of left embankment	19 11 feet	Height of Strand	17 01 feet.
Ditto right ditto	15 12 „	High water, June, 1868	13 58 „
High water, June 1868	13 12 „	Ditto, Oct, „	13 25 „
Ditto Oct, „	12 17 „	Mean sea level,	0 00 „
Mean sea level,	0 00 „		

From a document sent me before, I gather that the average spring tides throughout the year rise through 14 and 10 feet at Diamond Harbour and Calcutta. Hence I add to the above—

Mean high water of June and October 1868	12 65 feet	Mean high water of June and October 1868	13 41 feet.
Mid tide line	5 65 „	Mid-tide line,	8 41 „

This seems to show that the fall of the river from Calcutta to the sea is 8 41 feet, and from Diamond Harbour to the sea 5 65 feet. I may add to the above data that the Cyclone of 1864 occurred at neap-tides. Also that in that Cyclone, the Strand Road, Calcutta, was about 3 feet deep in water (Report, p 122).

The facts, then, for my present purpose, show that in the Cyclone of October 1864, the river-wave rose at Diamond Harbour 11·52 feet above high spring tide mark, or about 25·52 above low water mark, overtopped *the embankment by 4 58 feet, and flooded the Strand at Calcutta 3 feet deep*. Now the average spring tide through the year rises through the same space, viz, 14 feet, both at Kedgeree and Diamond Harbour, and it is confined within the banks of the river. Hence I conclude that, if the river be embanked from the sea to Diamond Harbour high enough to keep in the river-wave, a rise of 30 or 40 feet above low water mark off Kedgeree, will produce a rise of 30 or 40 feet at Diamond Harbour above low water mark. This is 4·48 or 14 48 higher than the river-wave of October 1864, that is, 9 06 or 19 06 over the embankment above Diamond Harbour, where the new higher embankment from the sea is supposed to terminate. Now 4·58 : 9·06 or 19·06 = 3 : 5·93 or 12·48. That is, as the inundation, north of Diamond Harbour in the Cyclone of October 1864, produced a flooding of 3 feet on the Strand in Calcutta, so a similar Cyclone would produce a flooding of about 6 or $12\frac{1}{2}$ feet, according as the wave off Kedgeree rose 30 or 40 feet, if the river be embanked from the sea to Diamond Harbour, so as to keep in the water in that part.

I do not consider this result so trustworthy as that in the case considered in my former letter, simply for this reason that the numbers are smaller

and therefore their ratios more liable to misrepresent. Yet I can see no reason why the result should not be even greater than this. It is, as I said, the best solution I can give It must be observed that the result would be increased if a Cyclone like that of 1864 were to occur at spring tides instead of neap, and the river wave were to reach Calcutta at the time of high water

As you have favored me with a copy of your note upon my former letter, I take this opportunity of making some remarks upon it.

In my letter under review I showed that if, *first* the Hooghly is embanked from the sea to Calcutta so as to confine the river-wave, we might, from the data before me, expect it to rise to "something like 29 feet" at Calcutta, and that if, *secondly*, the river is embanked only from Diamond Harbour to Calcutta, the rise might be 19 feet. It is the first of these that your note considers. You demur to my mode of obtaining this result But that my process of using simple proportion, to obtain the rise of the river-wave at Calcutta from that at Kedgeree, by means of the ratio of the rise of the tide at the two places, is not only reasonable, but in some cases leads to results under the mark, appears from the following considerations —From paragraph 3 it appears that the mean tide line rises from zero at Kedgeree to 8·41 at Calcutta, and that an addition of 7 feet at Kedgeree (the semi-tide) causes an addition of 5 at Calcutta Therefore, the rise during high tide from Kedgeree to Calcutta is from 7 to 13·41, which is a less rise than from 0 to 8·41. Hence, any greater rise than 7 feet at Kedgeree above the mid-tide will, unless other causes happen to modify its effect, cause a larger rise at Calcutta than at the rate of 5 . 7 feet, that is, the rise will increase in a higher degree than the simple ratio. the water has, in fact, a less and less steep ascent to surmount the more water there is. That this is actually the case in some instances, Table No 25 will show. From that table, I pick out the data opposite May new moon, June new moon, and October new and full moon, and construct the following table —

Ratio of tide at Calcutta to that at Kedgeree.

Average, ..	..	..	10 ÷ 14 = 0·714
May new moon,..	..	..	12-10 ÷ 16-5 = 0·781
June " " ..	.	..	12-10 ÷ 16-2 = 0·793
October new moon,	.	..	9-9 ÷ 14-4 = 0·680
" full "	..	..	10-1 ÷ 15-4 = 0·658

The average (which I have used) makes the tide at Calcutta 0·714 of that at Kedgeree, whereas in May and June (both cyclone months) a tide, higher than the average 14 feet, produces a rise at Calcutta higher in proportion than the average would give. In October (the month in which the Cyclone under review occurred) the rise at Calcutta is less in proportion than the average. Hence, if the Cyclone of *October* 1864 was so disastrous, what might not one in May or June produce, if otherwise so circumstanced as to generate a dangerous river-wave?

The remainder of your Note refers to the details of my explanation of the generation of the river-wave. The matter noticed above is the most important part of my letter. But upon the other points I will also comment—

1st.—I doubt whether the river-wave moved "at only half the rate" of the tidal wave. It appears to have moved variably, "according to its own law of wave or tidal motion, *more or less modified in its course by the winds it encountered*" (*see* my former letter) By comparing pp 112, 122 of the printed Report, you will find that it was at Kedgeree two hours before the time of high water, and at Calcutta about one hour before high water, so that it moved up on the whole somewhat slower than the tidal wave would have moved. The anomalous report from Diamond Harbour (which I have already noticed) makes the river-wave reach that place half an hour *after* the time of high water! This must be a mistake.

2nd—You say that "it does not appear that the phenomenon of the tide-wave was retarded on that day, and therefore it may be presumed that it proceeded at its usual rate." But the tidal wave on that day was not discernible. It was absorbed in the far more important river-wave. You will see that some of the observers very properly use the expression, —"high tide would have occurred" at such an hour.

3rd.—I have nowhere said that "the river-wave moved wholly independent of the wind;" quite the contrary What I said was "the river-wave and the calm or central part of the storm move independently of each other" when the storm reaches the continent. They were *necessarily* connected when

the storm was at sea. When they come to land, their connexion is broken.

4th.—I did by mistake read "north of Saugor Island" instead of "Saugor Point" The correction gets rid of the objection, that the wave may have been 30 feet at Cowcolly, 40 feet out in the river, and comparatively nothing on the north of Saugor Island.

5th.—In the words "it was the wind from the south which crowded up the water in the contracting part of the river," I meant by the "contracting part" the whole from the sea to Diamond Harbour.

Before concluding, I will observe that the circumstances of the Cyclone of 1st November, 1867, which, I am told was as furious as that of October 1864, confirm my view of the generation of the river-wave. In that storm, the centre of which, I learn, passed northerly on the *east* of the Hooghly, no dangerous wave was produced in that river, whereas, as I learnt incidentally when at Burrisal a month ago, in those parts on the east of the Sunderbunds, the rise of the water was very great, though in the Cyclone of 1864 no rise was seen Those parts were, in fact, too far off in 1864 In 1867 they occupied a place, in reference to the centre of the storm, precisely similar to that which the River Hooghly occupied in 1864.

From Colonel R. Strachey, R E, *Offg. Secy to the Government of India, P W Department, to the Joint Secy to the Government of Bengal, P. W Department, Irrigation Branch*

Dated Simla, the 26th April, 1869

I am directed to acknowledge the receipt of your letter No. 318 I., dated 9th March, 1869, forwarding a report by the Ven'ble Archdeacon Pratt on the subject of the probable effect on Calcutta of embanking the Hooghly from the sea, in the event of the occurrence of a cyclone similar to that of October 1864, together with a Note by yourself on this report.

The Archdeacon assumes that the rise of the storm-wave (or as he terms it the river-wave) at various points on the river, will bear the same relative proportion to the maximum rise as that observed in the ordinary tidal-wave, and the reputed rise of the river at the mouth of the Hooghly

in October 1864, having been 40 feet, he argues that the rise at Calcutta would have been 19 feet above the level of high spring-tides, had the river been completely embanked

In your Note on this Report, you state that you are not prepared to admit that the cases of a storm-wave and of an ordinary tidal-wave are analogous, and you refer to a previous paper by you on the same subject, in which you gave it as your opinion, that the contraction of the waterway would not tend to increase the distance up which the wave would travel, or the height to which it would be raised, and that the height of this wave is mainly dependent on the direction and intensity of the wind.

But admitting for a moment, the principle enunciated by Archdeacon Pratt, and adopting more certain data as to the height of the storm-wave of 1864, you calculate that the height which this wave would have reached at Calcutta, had the river been completely embanked, would only have been 8 feet above high spring-tides, which therefore, you consider is the greatest height which, under any circumstances, it would be necessary to guard against, and to do this effectually, would not, in your opinion, be either difficult or lead to excessive expense.

His Honor the Lieutenant-Governor is of opinion that the subject of protecting the Districts bordering the Hooghly should be further considered, and that if the project of embanking these Districts be decided upon, arrangements should be simultaneously made for providing protection for Calcutta

The Governor General in Council, after a consideration of these and previous papers on the subject, is of opinion that the collation of more facts is necessary to admit of a decision of any weight being come to In my predecessor's letter No 68 I, dated 25th April, 1868, it was suggested that a careful study of the tides would probably throw light on the question of the rise of the storm-wave in various parts of the river, and a remark to the same effect was made in Sir G. Airy's letter of 27th November, 1868.

It still appears to the Governor General in Council that a special study of the actual rise and fall of the tides in various parts of the river Hooghly under various circumstances, is the first essential towards arriving at any sound conclusion on the subject under discussion.

From a critical examination of the tides, in connection with the force

and direction of the wind at various seasons of the year, and in the different reaches of the river, selecting for special examination and comparison, parts of the channel where the waters were strictly confined within the banks, and parts where the moving water could escape into side channels, data would be obtained which would, at all events, indicate what is the tendency of the embankments in respect to raising the water in the upper reaches of the river, when there are unusually high tides and strong southerly winds at the mouth of the river These conditions would, so far as they went, tend to produce results analogous to those caused by a cyclone having its centre to the west of the channel of the Hooghly, which, as experience shows, is the contingency under which the dangerous storm-waves are formed at the mouth of the river

I am, therefore, to request that His Honor the Lieutenant-Governor will consider the subject in the light of these remarks, and lay before the Government of India a definite proposal for undertaking a series of observations of the nature referred to.

The question is of such great importance, affecting as it does the future safety of the large Districts on either side of the Hooghly, that the Governor General in Council has no doubt that the Government of Bengal will concur in the desirability of obtaining the greatest possible amount of information with respect to it, before either abandoning the scheme of embanking the river, or embarking in the large expenditure which its execution must necessarily involve

A series of observations of the nature proposed would, besides fulfilling the primary purpose for which it is proposed to institute them, furnish data of considerable value in elucidating the general phenomena of tides, regarding which much has yet to be learnt. The Governor General in Council would again indicate the Ven'ble Archdeacon Pratt as a gentleman whose opinion might usefully be taken, in preparing a scheme for systematic tidal observations.

The Government of Bengal will naturally enquire whether, at any former period, there has been a series of tidal observations taken in the Hooghly, and whether the record of those observations are forthcoming.

Correspondence.

The Editor acknowledges, with thanks, the receipts of the following papers :—The Gogra Crossing at Byram-ghat—The Abyssinian Telegraph—Irrigation in the Deccan—The Mississippi Report—Circular Brick Clamps—The Slide Rule—Suez Canal Dredgers—The Mont Cenis Railway—Pile Engine for Sea-works—G. T. Survey Report for 1867-68—Madras Water Supply—Saltpetering—Report on Drainage of Bombay—The Ceylon Railway—Report on Ceylon Public Works Department—The Sarvapilly Tank—Note on the Akra Brick Field.

In reference to No. CXC. of these Papers, the Editor has been requested to publish the award of the Building Committee, which is as follows :—

"The Committee of the Lahore Church Building Fund having carefully examined the several designs submitted, resolved unanimously at a final meeting held on Friday, the 17th instant—

"That no single design entirely fulfils all the necessary requirements, or would be adopted without modification, but judging of the comparative merits of the designs as fulfilling the conditions announced in the advertisements, the Committee are of opinion that the design marked " Apex " is that which, on the whole, appears most suitable and to which on these grounds the 1st premium of Rs 500 is to be awarded.

"On similar grounds that the 2nd premium of Rs 300 be awarded to the design bearing the device of a red trefoil.

"At the same time the Committee express their opinion that the design signed " Rex" is in itself by far the finest specimen of architectural art submitted, but does not meet the requirements of the present competition.

"On breaking the seals of the envelopes, the 1st premium was found to have been gained by Mr. E. I. Martin, Executive Engineer, Delhi, and the 2nd premium by Mr. Alex. Bryce, Delhi Railway, Mozuffurnuggur.

"The designs of the other competitors, whose names are not known, will be returned on application to the undersigned."

L. CONWAY GORDON, LIEUT., R.E.,

Honorary Secretary Lahore Church Building Fund.

To the Editor.

SIR,—I am very much interested in the subject of Bridges for Hill roads ; I therefore read with much interest the article No. CCII. on a Rope Bridge over the Che-

nab, but in examining the statement of estimated cost, I was struck with the very small amount entered for the different articles. In the description, it is stated that „ the ropes you mention " are made of very good native sootlee (hemp), the charge for 2035 maunds of this sootlee is set down at Rs 106-4-0, or nearly 10 maunds per rupee Raw hemp is now selling at 6 rupees per maund, a short time ago it was 4 rupees per maund, but if hemp made into sootlee can be purchased at 1 anna 7 pie per maund at Madhopore, there is a lot of money to be made by it Ash pieces for foot way are down at 2 Rs The roadway of sound clean deodar, $\frac{3}{4}$" thick, notched, length 195 feet × 2 feet wide, cost Rs. 12, this is less then $\frac{1}{2}$ anna per square foot

I think it is clear from this that there is something wrong, and an explanation is necessary.

Yours faithfully,

A. C

Correspondence.

THE Editor acknowledges, with thanks, the receipt of the following Papers—Drainage of Bombay—Sun-Dials—The Hoffmann Brick Kilns—The Luckawully and Masoor Reservoirs—Timber Trees of the Hullamully Hills—The Great Circle Track—On the Motion of a Wave—Kurrachee Harbour Works—Irrigation in the Madras Presidency

THE KILAR BRIDGE

To the Editor

MY DEAR SIR,—In the February number of your "Professional Papers," there is a criticism on the figures of Mr Sparling's account of the Kilar Bridge in No. CCII of November 1868

In that number, there is a misprint, stating the quantity of "Sootlee" as 2,035 maunds, whereas it ought to be "20 maunds 35 seers, at Rs 9-12-0 a maund"

The critic, however, should hardly have been misled by the error, for if he considered a moment, that the distance from Madhopore to Pangi (taking the shortest route) is over 15 marches, it is obviously impossible to carry 2,035 maunds of any substance whatever, to such a distance for only Rs 62

With regard to the cheapness of the ash pieces on the foot-way, which are about 1½ inches in diameter and 3 feet long, a common coolie could cut twice as many as required, in a day, without going farther than 100 yards from either end of the bridge.

The flooring seems cheap, but the Forest Officers, when making improvements in Pangi, have to pay only for labour, not for timber

If you will give a place to these remarks in explanation of the original report, and in reply to the criticism, you will be doing a kindness, as well as justice, to Mr Sparling, whose efforts, in connection with the bridge, were on all hands admitted to be in the highest degree praiseworthy

Yours truly,

B POWELL,

Offg. Conservator of Forests, Punjab

LAHORE, *May 25th*, 1869.

To the Editor

MY DEAR SIR,—I am collecting materials for a volume of Indian Specifications, something like Blenkarn's, to include also Specimen Forms of Tender and Agreement, Conditions of Contract, &c May I ask the readers of the "Professional Papers," especially officers of the Public Works Department, to assist me by sending me copies of any Specifications, Forms of Tender, &c, which they may have had occasion to draw up for contract work? As these are usually printed, it will not be much trouble to post a copy, and when the papers are in manuscript, I shall be happy to defray the cost of copying

Yours faithfully,

R GERVASE ELWES,

Executive Engineer, 2nd Division, Sirhind Canal.

LOODIANA,
July 10th, 1869.

Correspondence.

THE Editor acknowledges, with thanks, the receipt of the following Papers.—Ceylon Weights and Measures—Surveying Operations in Abyssinia—The Pennair Bridge, Madras Railway—Canals *versus* Railways—Railway Boat Bridges—The Soane Anicut—Sluices of the Mahanuddy Anicut—Fouracres' Tool for Well-sinking.

To the Editor.

DEAR SIR,—Will you allow me to correct one or two clerical, and other, errors, in Major Mullins's Report on the Luckawully and Masoor Reservoirs published in the August number?

The waste weir, for the former reservoir was intended to discharge 8 millions of cubic yards per hour, which is equivalent to about ⅛th-inch running off the drainage area per hour The rates of eight annas per cubic yard, for selected earth, and five annas for ordinary earth embankment, have been taken throughout, the two annas mentioned by Major Mullins, page 257, was for *shifting* soil, which had already been reckoned as excavated under another heading, so that no addition is needed on this account.

To the estimate, on page 255, must be added sluices, pipes, temporary dams, road diversions, plant, building and management, which amounted in my estimate to Rs. 12,07,890, thus bringing the entire cost up to Rs 43,05,000.

In page 258, Major Mullins has mistaken my meaning as to the disposal of the Irrigation water after leaving the sluices Pits had been dug, and the existence of rock had been determined, but it seemed to me doubtful whether the surface when bared of the soil, would be sufficiently regular to allow of the water running down in a sheet, or whether it might be so irregular as to collect the water into torrents whose action it might not be able to withstand On this account, I provided for retaining walls and aprons, and their cost is already included in the item of Rs 47,100 in the estimate, page 255. The existence of a rock foundation for the waste weir has also been ascertained, although its exact line cannot be fixed without a great deal of excavation of the upper soil

As to the cost of permanent establishment, there is no reason why a work which is very expensive as compared with its extent or bulk should cost as much for superintendence as inexpensive earthwork, costing the same sum, but spread over many miles The estimate already allows for petty superintendence

Since Major Mullins's Report was written, the water spread of the reservoir has been surveyed. It appears that the first rough survey had missed a large valley on the west side. The area is now found to be 34 15 square miles, and the contents are computed at 1650 millions of cubic yards. At Major Mullins's rate of 10,000 cubic yards stored per acre irrigated, the cost per acre would be about Rs. 26, and the gross revenue, at Rs. 6 per acre, about 26 per cent

BELLARY,
September 13th, 1869.

Yours faithfully,
G GORDON

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